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**QUICK DISCONNECT MECHANISM DEVELOPMENT
PHASE I: FEASIBILITY STUDY (U)**

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FOR THE COMMANDER



KENNETH R. BOFF, Chief
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13. ABSTRACT (Maximum 200 words) Night vision goggles (NVG) greatly enhance the aviator's war fighting capability during hours of darkness. The addition of aircraft flight symbology directly onto the NVG would allow the aviator to view vital information without the need to look down at the aircraft console. One method of adding the display to the NVG is through the use of a fiber optic cable (FOC). During ejection or emergency ground egress the FOC must quickly separate from the aviator without increasing the risk of injury. This report explores several alternatives in quick disconnect mechanisms.				
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This document is the final technical report on the Quick Disconnect Mechanism Development, Phase I: Feasibility Study, Task 53B of contract F33615-89-C-0574. The effort was performed in the Military Systems Division of the Defense Electronics Systems Center within Systems Research Laboratories, 2800 Indian Ripple Road, Dayton, OH 45440; SRL is a Division of Arvin/Calspan Corporation. The effort was performed during the September 1991 to February 1992 time period.

The USAF Program Manager for this effort was Preston Scott Hall, AL/CFA-HMST ADPO and the Deputy Program Manager was Capt Larry L. Wiley, AL/CFA-HMST ADPO, Wright-Patterson AFB OH 45433-7022. Mr. Larry Meyers of SRL was the Principal Investigator and Program Manager on this project. Mr. James Riddell, III, SRL, also contributed to this investigation. In addition to the USAF Program and Deputy Program Manager, significant contributions were made to this study by Capt James Schuren, ASD/YPDD and CMSgt Stan Smigel, HSD/YAG.

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SECTION 1.0 INTRODUCTION

1.1 Description of the Problem

The purpose of the Fiber Optic Cable (FOC) Quick Connect/Disconnect (QCD) Mechanism development is to define requirements and subsequently design and fabricate a QCD for a coherent FOC. This study, the Phase I Feasibility Study, describes the basic aircraft layout of potential FOC systems and then develops and evaluates quick disconnect mechanisms for a variety of Heads-Up Display (HUD) system configurations which will permit rapid egress from an airplane. The FOC is used to transmit imagery or symbology from a video generation device to various Helmet Mounted Display (HMD) configurations in high performance aircraft. HMDs may be stand-alone units or integrated into an aided viewing device as a type of HUD. A crewman must be capable of rapid egress, which includes both ground egress and ejection, while the FOC is attached to the HMD; in addition, the crewman must have free and unimpeded movement while performing his mission.

1.2 Study Approach

1.2.1 Background

Fiber optics-based HUD systems are currently in use with Army and Air Force helicopters and the Air Force B-52, providing symbology type information into the AN/AVS-6 Night Vision Goggle (NVG). Figure 1-1 shows a basic block diagram for one of Systems Research Laboratorie's NVG/HUD configurations from the data generation point to the crewman's display. In this configuration, the desired aircraft data, Terrain Following/Terrain Avoidance (TF/TA) information, etc., are projected on the end of a 400 x 400 element FOC which coherently conducts the image to the HUD input optics. The present system thus has a single solid FOC with two connectors: a quarter-turn electrical type connector at the VSD (CRT) end and a sliding fit with ball detents at the HUD end. Two major factors make this configuration unsuitable for high performance, ejection seat configured aircraft:

1. The AN/AVS-6 is not ejection compatible and has a large moment of inertia which exerts excessive neck loads during high Gs.
2. The FOC is not readily separable from the crewman for rapid ground egress or ejection. Both routing of the FOC and FOC connector configurations affect emergency egress suitability.

SRL BASELINE NVG / HUD FOC CONFIGURATION

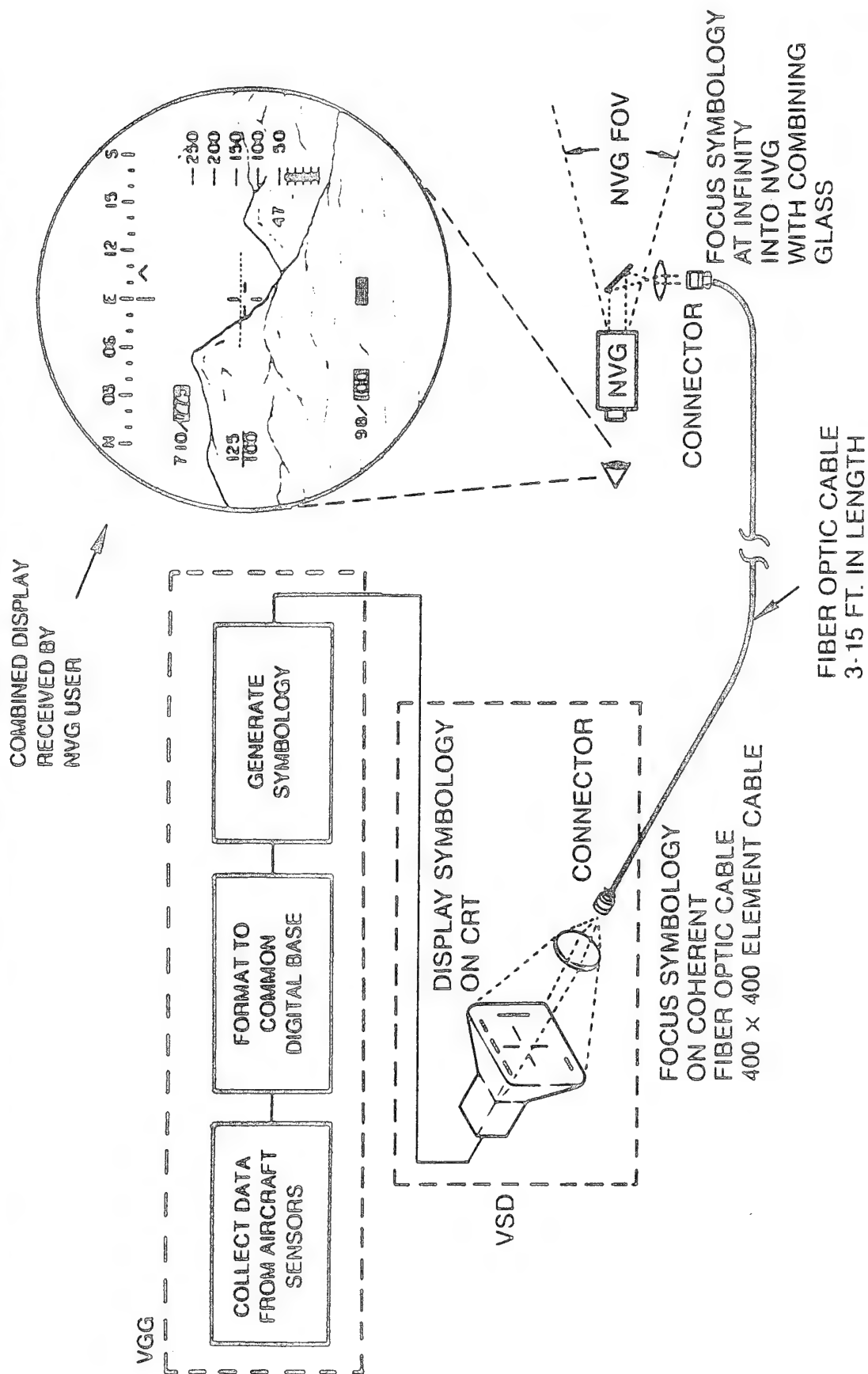


Figure 1-1. Night Vision/Head-Up Display Block Diagram

Although HUDs for NVGs are used as FOC QCD candidates throughout this report, it should be made clear that any type of HMD, utilizing symbology or imagery, is equally applicable to this technology.

The ejection compatible, close to the face center of gravity NVG requirement has several candidate solutions, including the Eagle Eye® and Merlin NVGs. Both of these NVGs have HUD ports that are compatible with the present SRL FOC. However, at this time there is no FOC with the requisite rapid egress/ejection characteristics to provide HUD symbology or imagery to the candidate NVGs. This study arose from the requirement to supply such a compatible cable with optimized interface to the NVG, the crewman, the ejection seat, and aircraft cockpit. Reflecting true system impact, each cable/quick disconnect configuration has potential effects on all other components of the HUD subsystem, crewman, and airplane.

1.2.2 Study Elements

Major components of the FOC QCD study include review of ejection seat environment, HUD system definition and associated FOC routing, crew/seat/helmet interoperability, and detailed design and evaluation of QCD candidates. A set of aircraft candidates for Eagle Eye® and Merlin were selected, and their cockpit and ejection seat configurations documented. The candidate aircraft are:

Aircraft	Seat Type/Angle	Number of Crew (with Ejection Seats)
A-10	ACES II/17°	1
B-52	Martin-Baker	2
F-15	ACES II/17°	1
F-16	ACES II/34°	1

Due to the limited availability of aircraft cockpits or accurate mockups, only the B-52 and F-16 were examined in detail. This is reasonable since the F-16 uses the Aces II seat, the standard for all new U.S. Air Force high performance airplanes, and the B-52 must be analyzed separately since its ejection seat, configuration, and size differ totally from the other candidates. Performing detailed installation analysis of candidate HUD electronics, FOCs and QCDs on all the potential high performance airplanes is beyond the scope of this investigation and is not necessary to design a universally adequate QCD.

Details of the B-52 and F-16 ejection seat, cockpit, and crew interface were compiled to provide the framework to evaluate both functionality of the HUD system within the aircraft and the candidate QCD mechanisms developed. Detailed photos and three views of the Martin-Baker and Aces II seat were obtained, and visits to cockpits and mockups at WPAFB were made. Various USAF personnel at WPAFB were interviewed to determine crew mission tasks within the cockpit that would impact HUD system design as well as rapid egress and ejection requirements. One of the important facts discovered early in the cockpit definition phase was that the standard helicopter HUD system installation with large VSD units would not be desirable or even possible in the high performance aircraft; the much more spacious B-52 cockpit is at present configured with standard size VSD units. With this condition established, the VSD design concept for this study was amended to include miniature tube assemblies performing the same function but in much smaller packages. Reduction in package size provided more flexibility in mounting the VSD, potentially shortened the FOC, and reduced the requirement for armored FOCs.

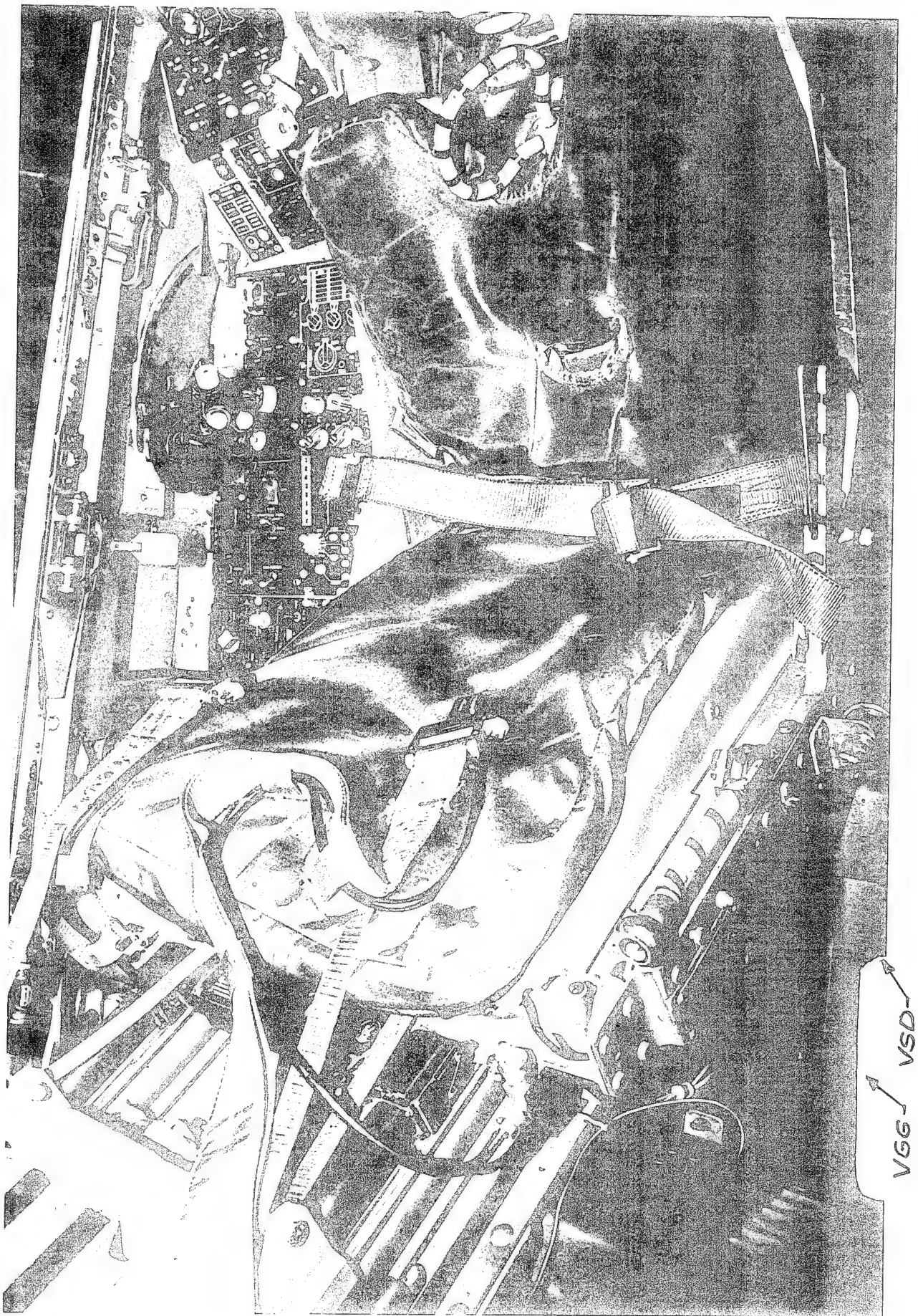
A large number of QCD configurations were identified based on the general HUD, FOC, aircraft, ejection seat, crew, etc. considerations. To the maximum extent that they could be identified, reliability, maintainability, and design risk factors were also used to delimit the selections made. Once the selection of HUD configurations and related QCD candidates was accomplished, the major design phase of the study was completed. In many cases, lab mockups with production NVG/HUD FOCs were used to examine cable imagery with different types of connector schemes. After candidate designs were completed in sufficient detail, a matrix of QCD characteristics was completed, including performance, cost, reliability, maintainability, technology risk, manufacturability, and advantages/disadvantages. Four top candidates were chosen for critical examination, with the best of these recommended for fabrication and test in Phase II of this effort. A Level II functional design drawing set of the recommended configuration was then completed. At the conclusion of the study, a Phase II fabrication and test program was developed for the optimum QCD and FOC configurations.

SECTION 2.0 REQUIREMENTS AND DESIGN GOALS

2.1 Ejection Seat and Cockpit Environment

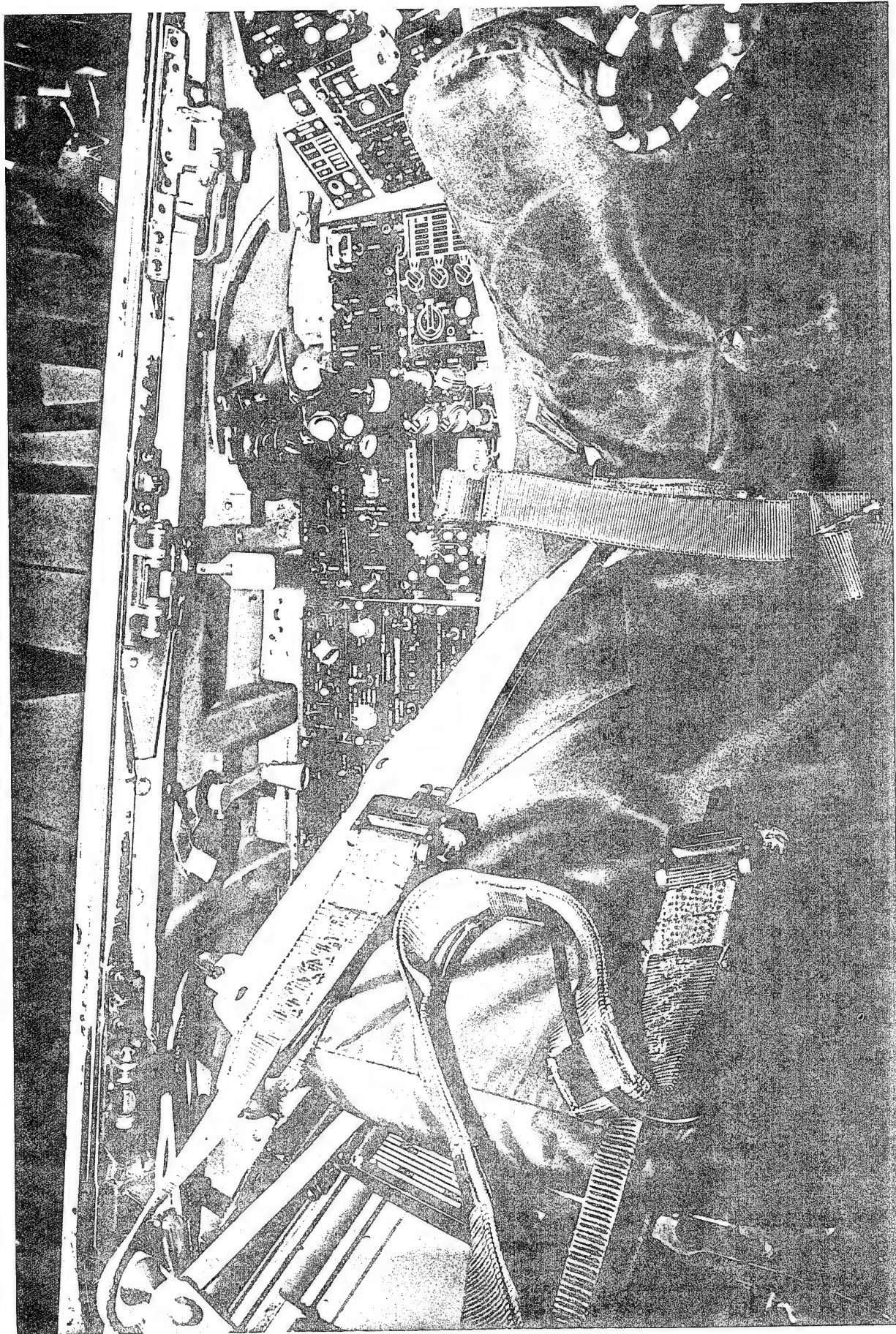
The F-16 cockpit available during the study did not have an Aces II seat. However Aces II seat data was available from the manufacturer to visualize the differences. Figure 2-1 shows the seat from the right side of the cockpit. From this photo, space behind the seat can be observed in which a Video Graphics Generator (VGG) could be located. Then with a bracket mounted to the aircraft, or mounted to the side of the Aces II seat, a miniaturized VSD could be placed just behind and to the right of the pilot's hip. This would provide a convenient location and permit the use of a relatively short FOC. A VSD control unit is required which allows the pilot to select what information he would like displayed to the HUD, and control the image brightness.

A HUD candidate space that would be convenient to reach and operate was investigated but none was found. Figures 2-1 & 2-3 show the left side of the F-16 cockpit which is very busy. Figure 2-2 shows the right side of the cockpit which also appears well utilized. Figure 2-4 shows the front area of the cockpit but no unused space. Figure 2-5 shows the top portion of an Aces II seat. A tape measure on the seat cushion indicates the approximate location of the pitot tubes. The photo indicates 34 inches above the cushion which is very near the height of the HUD port on a 95 percentile pilot. This is important in our cable routing to avoid interfering with the air flow to the pitot tube during ejection on the ACES II ejection seat.

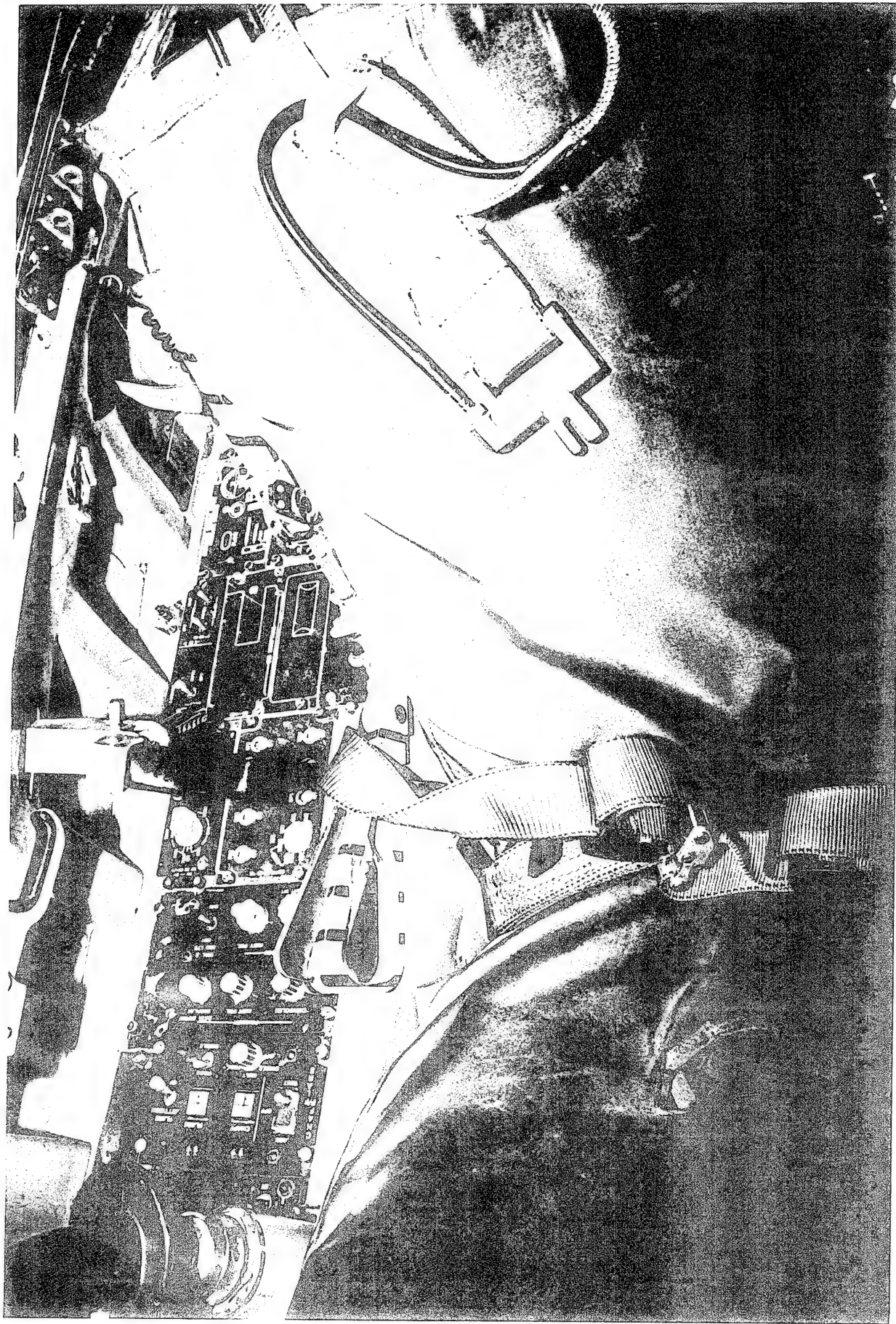


Potential space behind seat for VGG Unit. With special bracket VSD could be mounted at right side of seat.

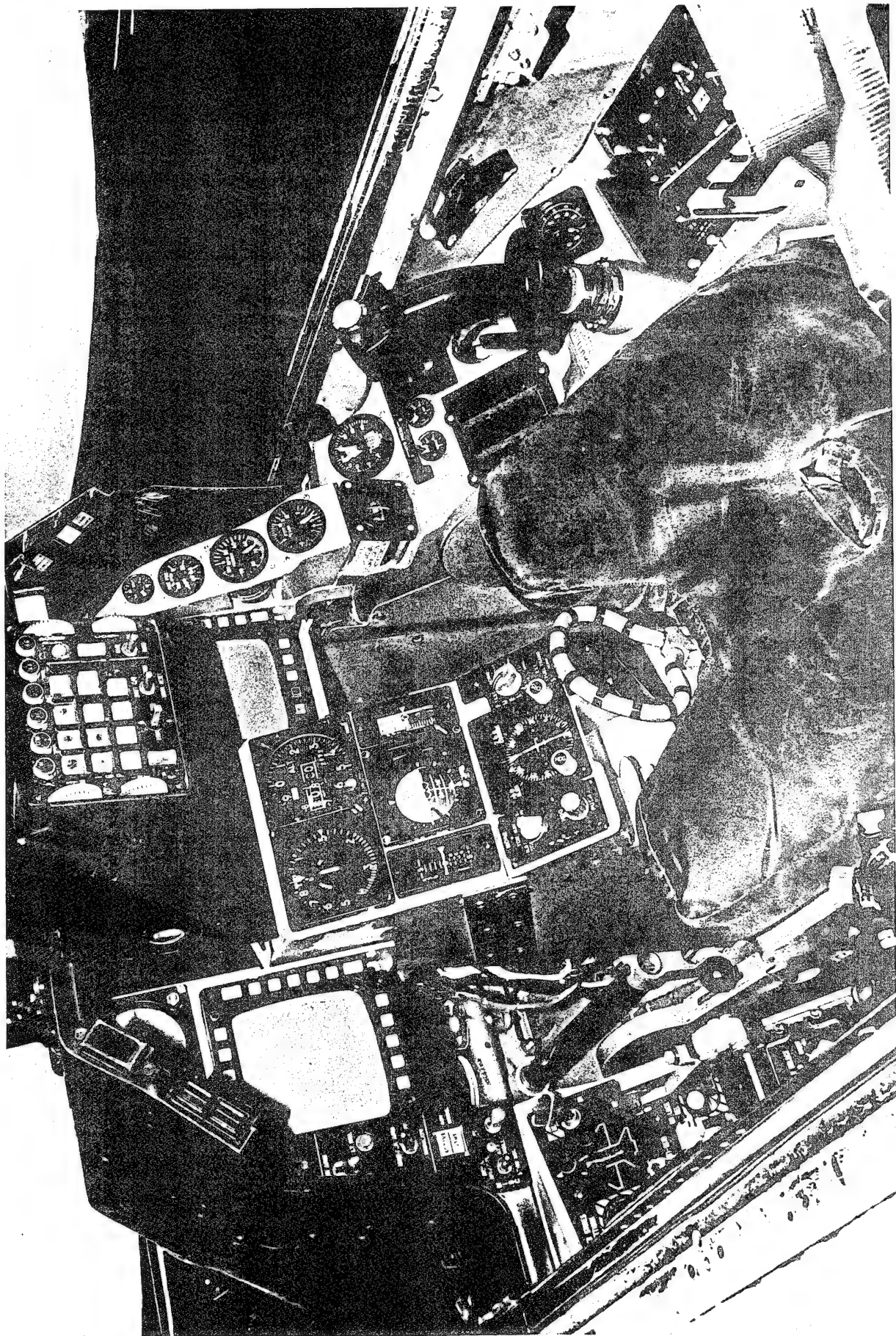
Figure 2-1
6



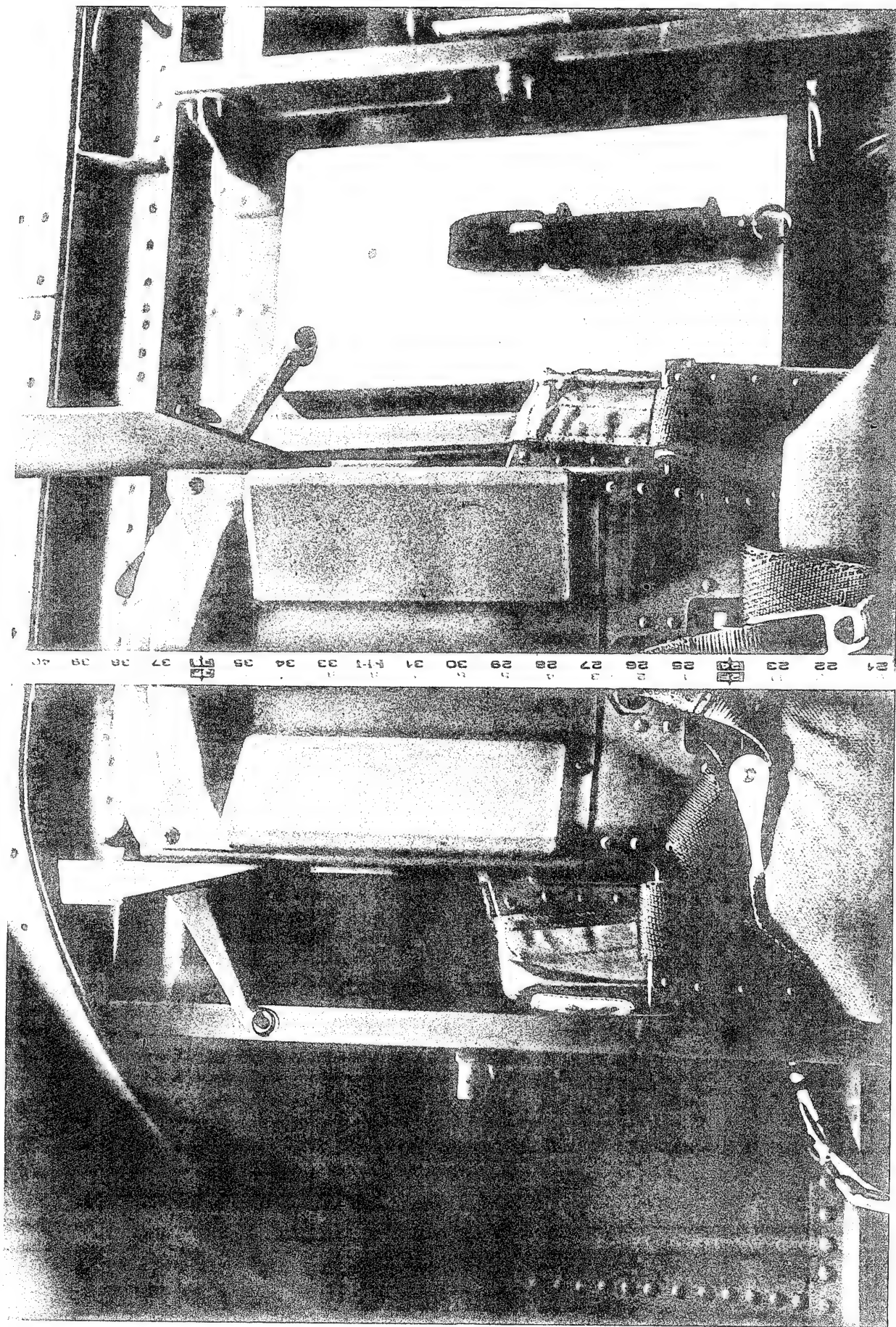
Left side of F16 cockpit found no room for VSD control unit.



Right side of F16 cockpit found no space for VSD control unit.



Front of F16 cockpit found no space for VSD control unit.



Aces II seat pitot tubes located 34 inches above seat cushion close to HUD port level.

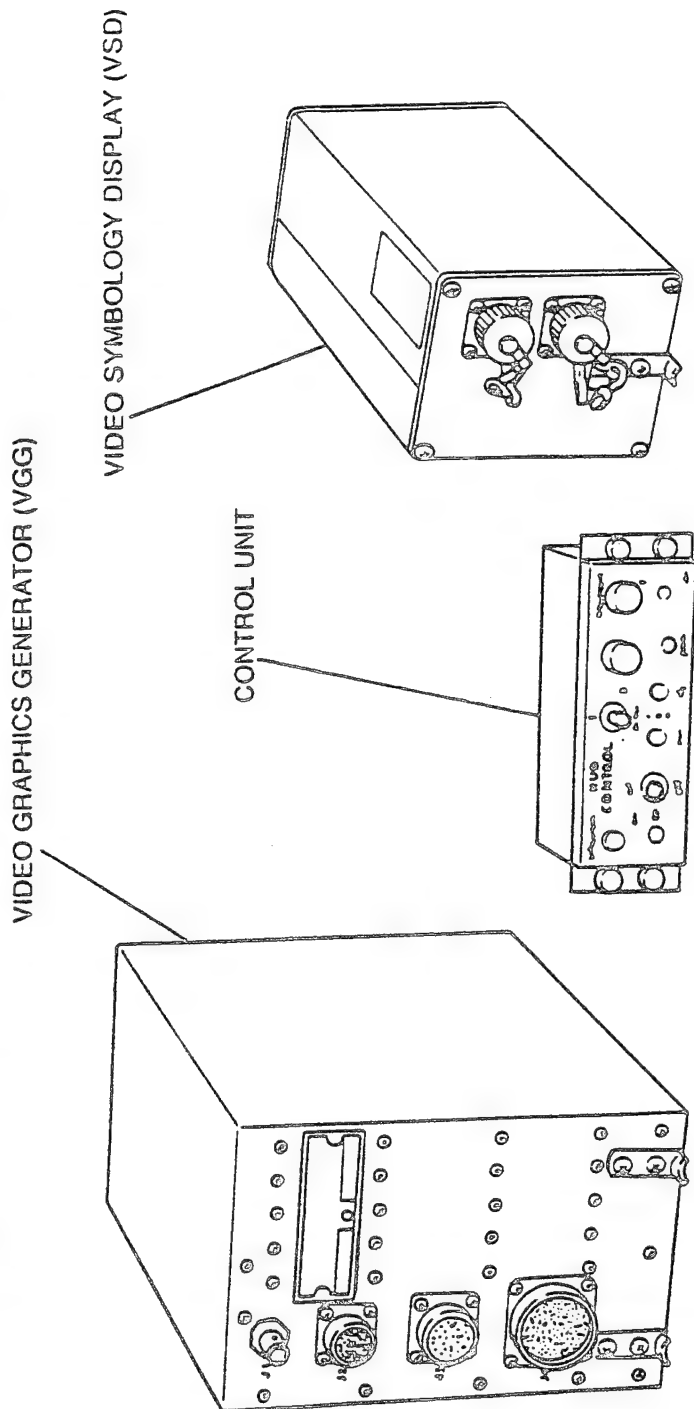
2.2 Review of Fiber Optic Cable HUD System Characteristics

The Quick Connect/Disconnect Release Mechanisms (QCD-RM) considered in this feasibility study are based on the generic requirements of the SRL NVG HUD configuration. Figure 1-1 showed the functional elements of the system but it is important to consider the actual hardware to be used if practical, flight worthy QCD-RM's are to be designed for high performance aircraft. Recommended modifications and improvements to the baseline system will be discussed in the following as requirements dictate. Previously designed equipment was built for large helicopters and large fixed wing airplanes such as the C-130 and B-52. Size and space constraints were not of the same magnitude as in fighter aircraft such as the F-15 and F-16. Figure 2-6 illustrates the actual electronic and video hardware required to produce a HUD image in the present system. Note that this is a two display system, with separate pilot/co-pilot controls on one control panel and two CRT's interfacing with separate FOC's on the single VSD Unit.

Aircraft inputs to the VGG may be either interfaced to the individual sensor such as the airspeed transducer or onto the 1553 A/B Bus accessible to all transducers. Most modern aircraft, including the F-16, use a 1553X Bus with the very great advantage that HUD interfacing becomes primarily a software task. At the output end of the present system, a robust FOC coherently transmits the VSD image to the head mounted HUD which can be a stand alone unit mounted on the helmet or a display integrated with a night vision device. As described in section 1.2.1, the SRL FOC was originally designed to mount on the AN/AVS-6 but has subsequently been interfaced with the Eagle Eye® and Merlin NVG's. Basic resolution properties of the present FOC, shown in Appendix A, can be observed in some investigations accomplished early in the program on the potential for utilizing QCD's in the middle of cables. Image degradation across optically coupled cable breaks show the resolution properties of the individual fibers.

The FOC that is supplied with the present SRL NVG HUD was designed to withstand physical abuse since in a helicopter installation it is in a position to be stepped on by the crew and it is frequently pulled and threaded throughout the cockpit from the VSD to the NVG HUD. This half inch diameter cable has several layers, including an interlocking spiral case made of stainless steel coated with silicone rubber and an outer anti-snap cover. Cable lengths vary from 86 inches to 180 inches in the installed systems to date, with average light transmission ranging from 40% to 30% respectively. A more detailed description of the present FOC and a potential improvement in size and flexibility is discussed in section 4.0. The major deficiency in the present FOC, for high performance aircraft use, is the connector configuration at both the VSD and goggle interface. A quarter turn connector at the VSD cannot be pulled straight off for rapid egress and the

PRODUCTION SYSTEM FOR ANVIS HUD



	SIZE (INCHES)			WEIGHT	
	HEIGHT	WIDTH	DEPTH	POUNDS	
VIDEO GRAPHICS GENERATOR	7-5/8	5-1/8	9-7/8	10	
VIDEO SYMBOLLOGY DISPLAY UNIT	3	4	9	5.5	
CONTROL PANEL	1-7/8	5-3/4	3	1	

Figure 2-6
12

pull-off connector at the AN/AVS-6 will only release over a limited pull angle. In addition, the remote position of the VSD makes it virtually impossible to avoid cable tangling in the cockpit or to perform a clean pull on a quick disconnect.

All of the parameters of the present AN/AVS-6 HUD FOC system were analyzed in the QCD-RM Phase I effort and characteristics were modified to obtain a rapid egress capability. Advantages of the FOC system include good resolution, minimum on-head weight, minimum HUD impact on the NVG, elimination of all electrical connections and a universal source of HUD information (i.e. a common VGG/VSD) were retained. A QCD-RM concept was developed which utilized the best features of the present configuration and modified those characteristics which did not support rapid egress.

2.3 List of Goals

The QCD must provide a convenient means to interface a FOC with the VSD and NVG. It must maintain good FOC to image plane integrity under all flight conditions. The QCD must provide hands off release from the VSD during rapid egress and ejection. The pull force for the QCD should be within 8-16 pounds and this force applied to the pilots torso rather than the head. The QCD must release with a pull directed within a 40° cone or greater. The QCD should have low technical risk, good manufacturability, minimum maintenance, and a low cost.

The FOC should be physically robust, flexible, light weight, small diameter, sufficient resolution for display, and short as possible. The free end of the FOC, if tethered to the pilot's harness, should be as short as possible to prevent flailing and designed to prevent snagging during rapid egress and ejection. The FOC should not interfere with head and body movement, nor interfere with seat ejection or seat/pilot separation. The FOC to HUD port may be accomplished prior to mounting NVG to helmet. The connection between the FOC and HUD port must release in case of helmet loss. The FOC routing to the HUD port should not disturb the air flow to the ACES II ejection seat pitot tubes.

During the course of the study it was also determined that a low voltage power and video QCD-RM was required between the VGG and VSD for selected VSD mounting configurations. The technology for the electrical QCD-RM is similar to that of the FOC version and the design has been accomplished for this effort.

2.4 Candidates QCD-RM Techniques

The initial list of FOC QCD techniques were mechanical, electro-mechanical, electro magnetic, permanent magnet, compressed gas and explosive. However, after discussing these alternatives with Air Force personnel responsible for maintaining this equipment, they strongly advised against devices that require

constant tracking. This would include anything that had it's own battery or needs scheduled checks and replacements to insure proper operation. Thus, devices that require explosives or compressed gas were not pursued. After evaluation of electro-mechanical latching and releasing mechanisms it was determined that their size and shapes were objectionable. Therefore the mechanical, electro-magnetic and magnetic QCD-RM concepts were developed.

2.5 Complete System Considerations

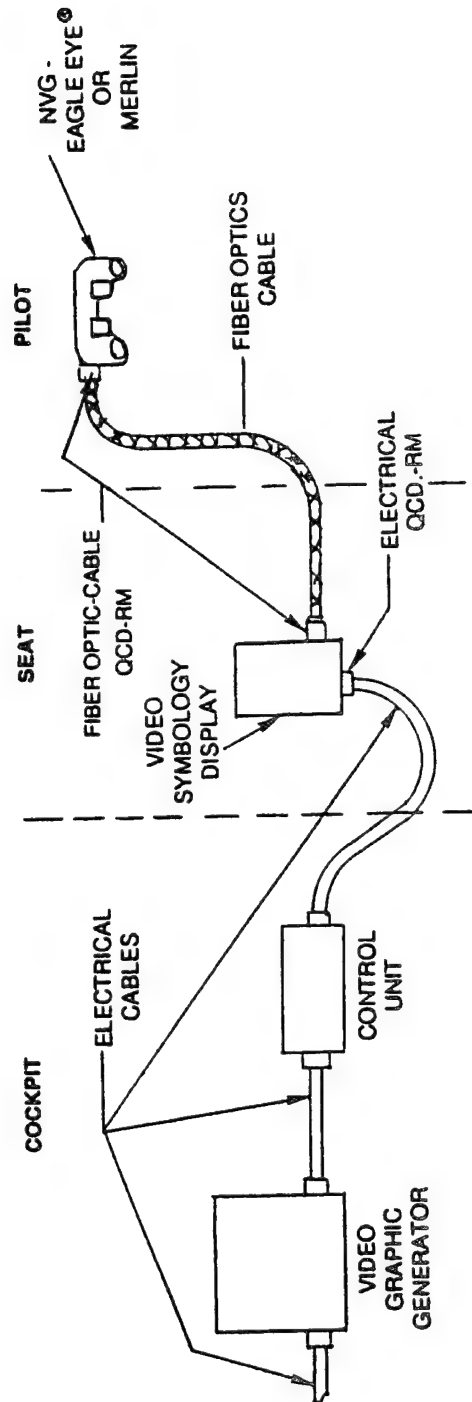
It is obvious that in order to use a FOC to transmit an image to the HUD port of a NVG there needs to be a source for this image. SRL's current production system was earlier described in the introduction. Some problems exist when integrating this system into a high performance aircraft due to the limited space available. After inspection of an F16 cockpit, potential space was found for the VGG to be located behind the seat. But the VSD is too large to mount in a convenient location or attitude. To remotely locate the VSD would require a long FOC which could cause problems for rapid egress and ejection. To make the cable in two pieces with a QCD-RM at a convenient location was then evaluated. See Appendix A for coupling tests and evaluation. This would cause a loss of resolution and possible light loss depending on the type of coupling between the two coherent fiber cables. This forced the consideration of a miniaturized VSD unit so it could be placed where it was needed. The control unit is small and could possibly be made smaller since only a single output unit is required. The location of the control unit was not determined as this would be a Phase II Task. However the VSD location is critical to the FOC routing so it's location was considered part of this development. The three configurations that are proposed are portrayed in figures 2-7 thru 2-12.

2.6 Configuration Descriptions

2.6.1 Seat Mounted Video Symbology Display (Figures 2-7 and 2-8).

The seat mounted VSD will required three captive nuts added to the right side of the ACES II seat. A standoff bracket for mounting the VSD would be provided. This should not affect the structural integrity of the seat. On this mount the VSD connector (QCD-RM) would be close to the pilot's hip; the FOC QCD would have a lanyard which will follow the cable routed under the pilot's right arm and attached to the pilot's harness. The lanyard will disengage the QCD-RM from the VSD as the pilot moves out of the cockpit for rapid egress. The lanyard will be sleeved to prevent snagging on anything in the cockpit during his egress. On ejection, the low voltage QCD-RM will release as the seat is propelled out of the cockpit. Then at the separation of the pilot from the seat the FOC QCD-RM will pull free from the VSD and the FOC will go with the pilot. Since by the time of seat separation

SEAT MOUNTED VIDEO SYMBOLOGY DISPLAY CONFIGURATION

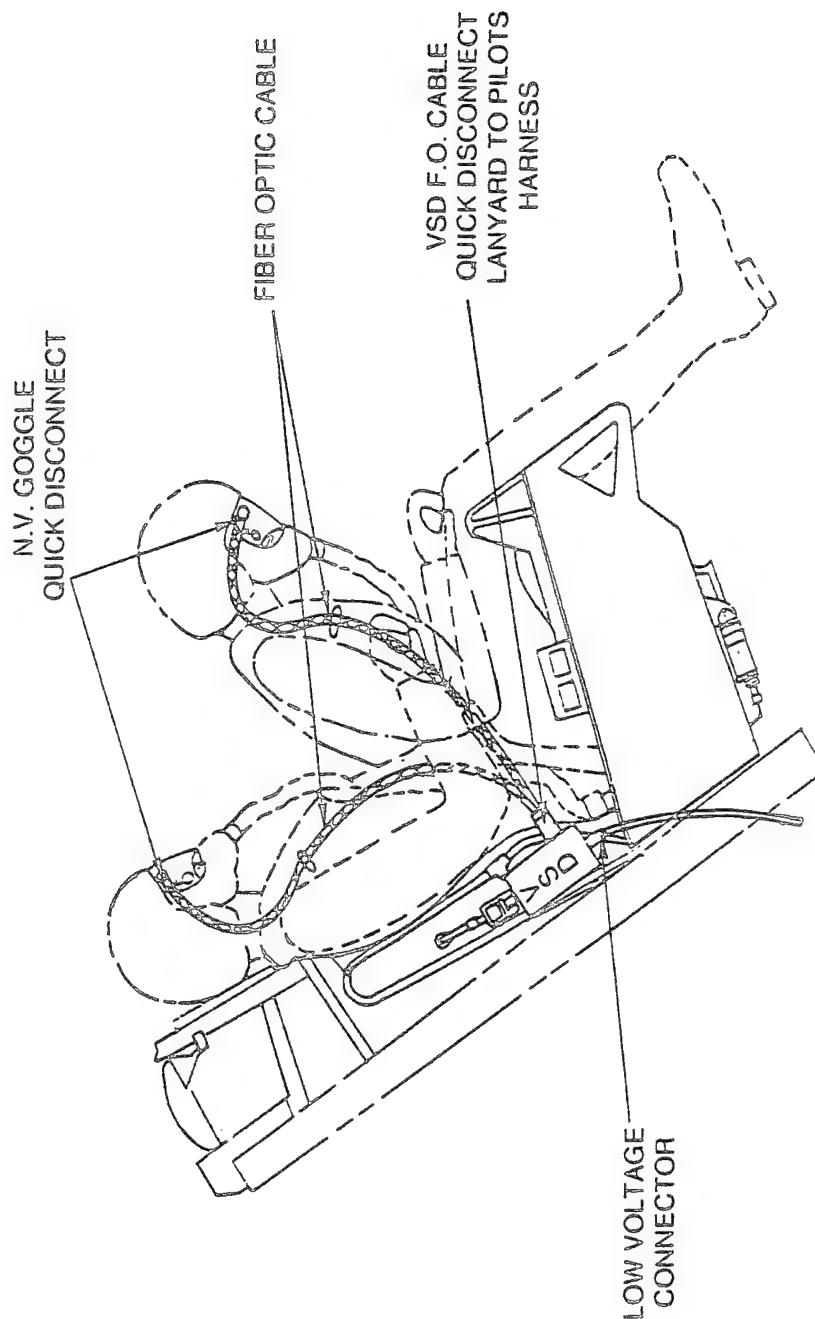


MODE	QCD/RM	DISCONNECT MECHANISM
RAPID EGRESS	FIBER OPTICS CABLE AT VSD	LANYARD TO HARNESS
EJECTION	LOW VOLTAGE ELECTRICAL CABLE	LANYARD TO AIRCRAFT
SEAT SEPARATION	FIBER OPTICS CABLE AT VSD	LANYARD TO HARNESS
LOSS OF HELMET	FIBER OPTICS CABLE AT NVG	HELMET INERTIA

Figure 2-7
15

SEAT MOUNTED VSD CONFIGURATION

- PILOT IN EXTREME FORWARD POSITION



FIBER OPTIC CABLE LENGTH WILL BE DESIGNED TO ALLOW
MAXIMUM PILOT MOTION DURING MISSION

Figure 2-8
16

the air speed of the seat and pilot should be greatly reduced, and with a short FOC end weighing 2 ounces, there should not be a FOC flailing problem. In the event of helmet loss the HUD end FOC QCD-RM will release from the NVGs due to the inertia of the helmet.

2.6.2 Aircraft Mounted Video Symbology Display

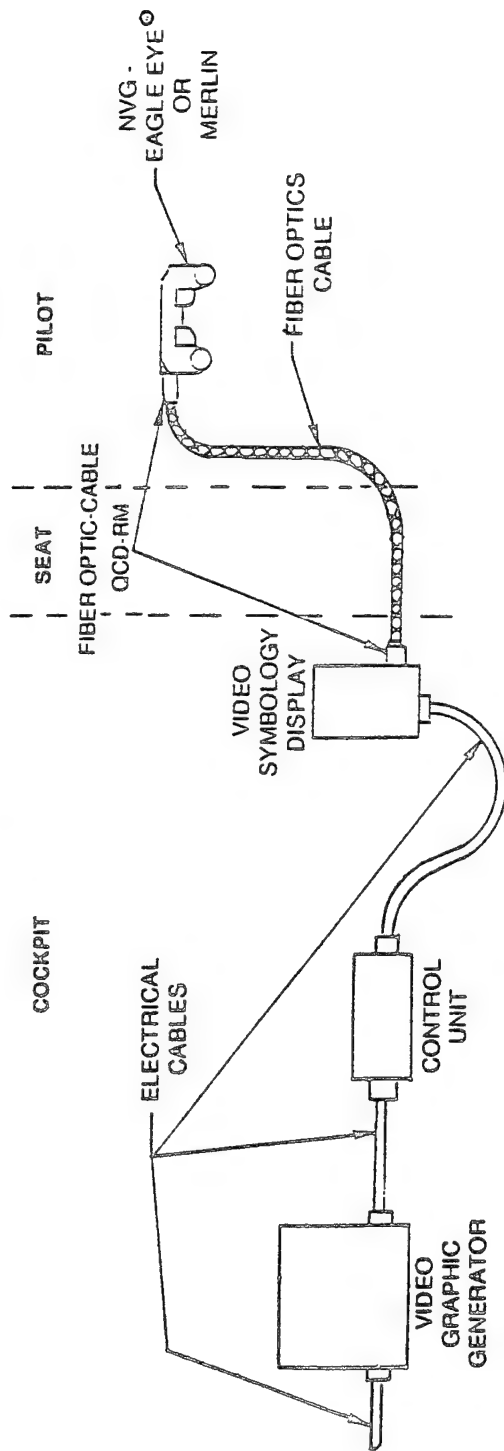
A configuration figure 2-9 and 2-10 bracket will be designed to mount the VSD just behind the guide rails for the seat. The VSD would be positioned so the QCD-RM and a 2 ft. FOC would be routed along the right side of the seat under the pilot's right arm. A lanyard attached to the QCD-RM will be fastened to the pilot's harness. A cover panel on the right side of the seat may be required to eliminate potential snagging on the fittings that are present. A lanyard is attached to the QCD-RM, sleeved to the FOC and attached to the pilot's harness. This lanyard will pull the QCD-RM free from the VSD during rapid egress or ejection. Because of the seat angle, the VSD will be mounted on a hinged mount to insure a reasonable release angle for the QCD-RM. The FOC length will increase to 3 ft., and require a longer tether. This will increase the flailing problem because the cable releases as the seat is ejected from the aircraft, bringing the free end of the cable into the wind blast at ejection speed. The VSD may be reconfigured so it could be mounted to the aircraft but positioned so the QCD-RM is nearly in the same location as the seat mounted VSD. This would permit the use of a 2 ft. FOC and considerably reduce the potential flailing problem. This will be further analyzed during Phase II. In the event of helmet loss, the QCD-RM at the HUD port would release from the NVGs due to the inertia of the helmet.

2.6.3 Pilot Mounted Video Symbology Display Configuration figures 2-11 and 2-12

The VSD would be mounted to the pilot's harness. There are two potential VSD designs. One would have the FOC QCD-RM located on the left side of the VSD as shown in figure 2-7 and another would have the FOC QCD-RM located at the top of the VSD. If the FOC QCD-RM is located at the top it may be possible to use a 9 3/4 inch long FOC. The side mount would require a 24 inch long FOC.

With the pilot mounted VSD configuration the low voltage electrical QCD-RM would disconnect on rapid egress or ejection. The VSD and FOC would remain with the pilot. In case of helmet loss the QCD-RM at the HUD port would release.

AIRCRAFT MOUNTED VIDEO SYMBOLOGY DISPLAY CONFIGURATION



MODE	QCD/RM	DISCONNECT MECHANISM
RAPID EGRESS	FIBER OPTICS CABLE AT VSD	LANYARD TO HARNESS
EJECTION	FIBER OPTICS CABLE AT VSD	LANYARD TO HARNESS
LOSS OF HELMET	FIBER OPTICS CABLE AT NVG	HELMET INERTIA

Figure 2-9
18

AIRCRAFT MOUNTED VSD CONFIGURATION

- PILOT IN EXTREME FORWARD POSITION

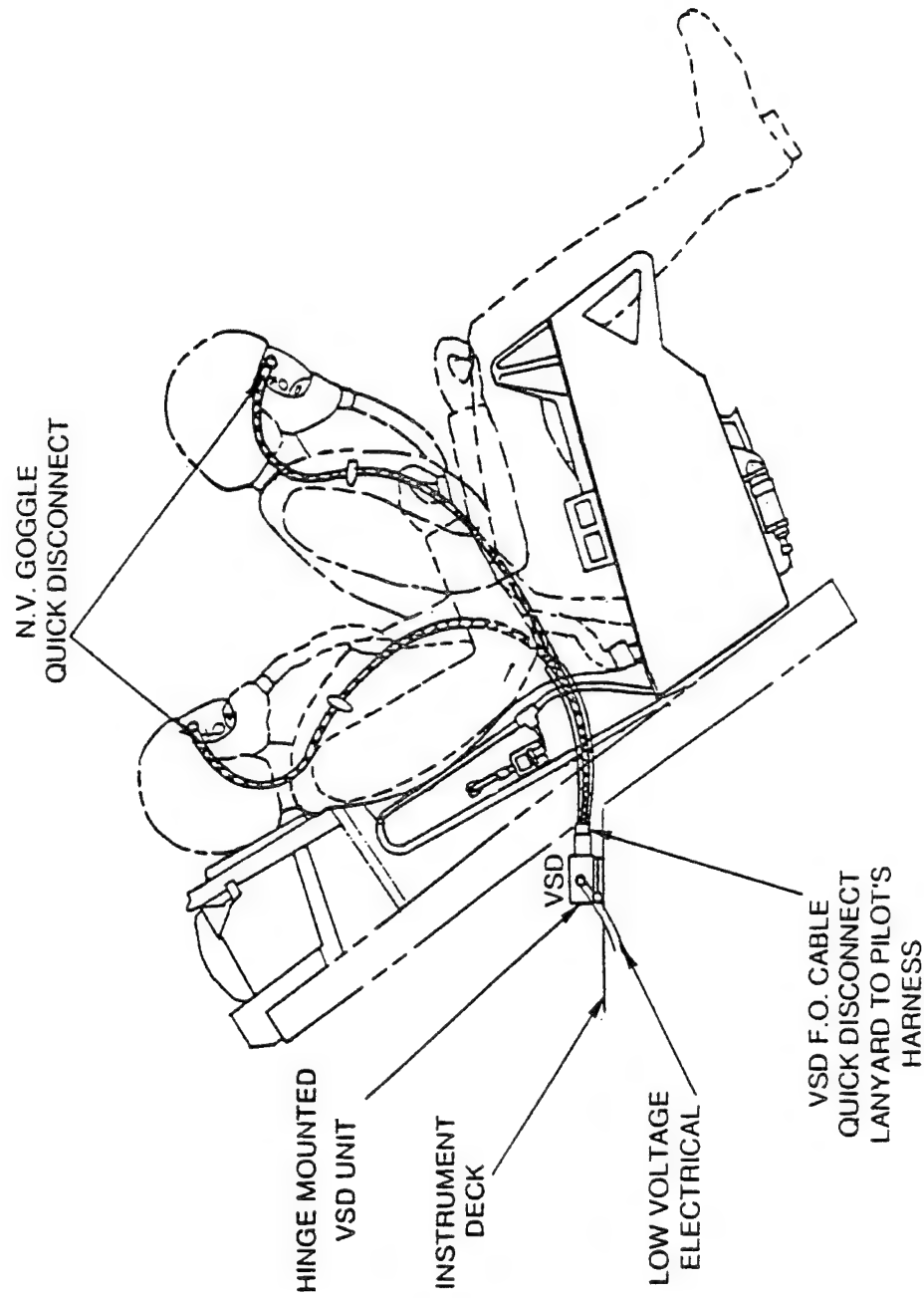
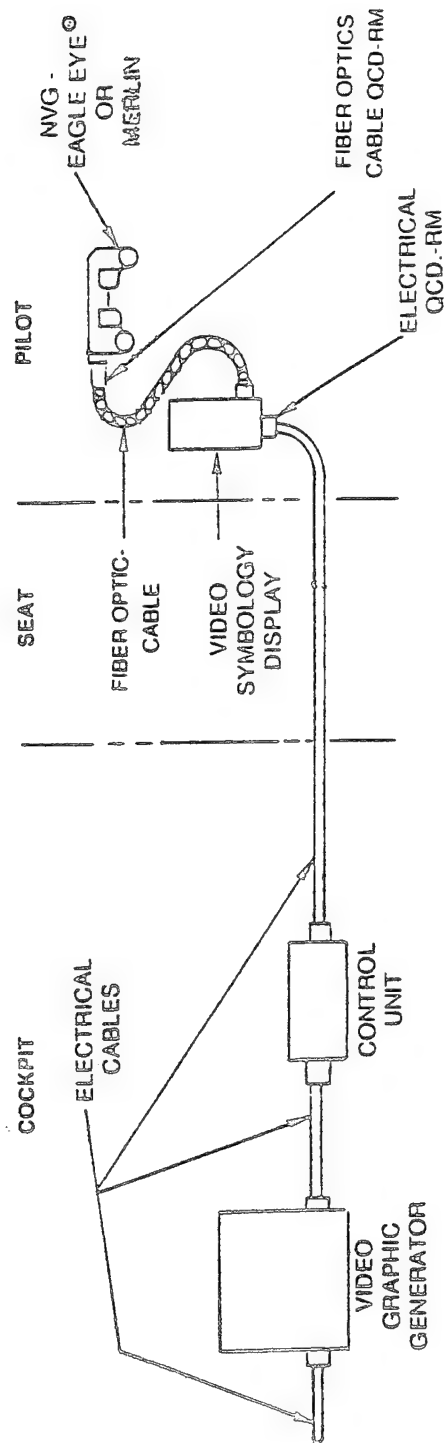


Figure 2-10
19

PILOT MOUNTED VIDEO SYMBOLOGY DISPLAY CONFIGURATION



MODE	QCD/RM	DISCONNECT MECHANISM
RAPID EGRESS	LOW VOLTAGE ELECTRICAL CABLE QCD AT VSD	LANYARD TO AIRCRAFT
EJECTION	LOW VOLTAGE ELECTRICAL CABLE QCD AT VSD	LANYARD TO AIRCRAFT
LOSS OF HELMET	FIBER OPTICS CABLE AT NVG	HELMET INERTIA

Figure 2-11
20

PILOT HARNESS MOUNTED VSD CONFIGURATION

- PILOT IN EXTREME FORWARD POSITION

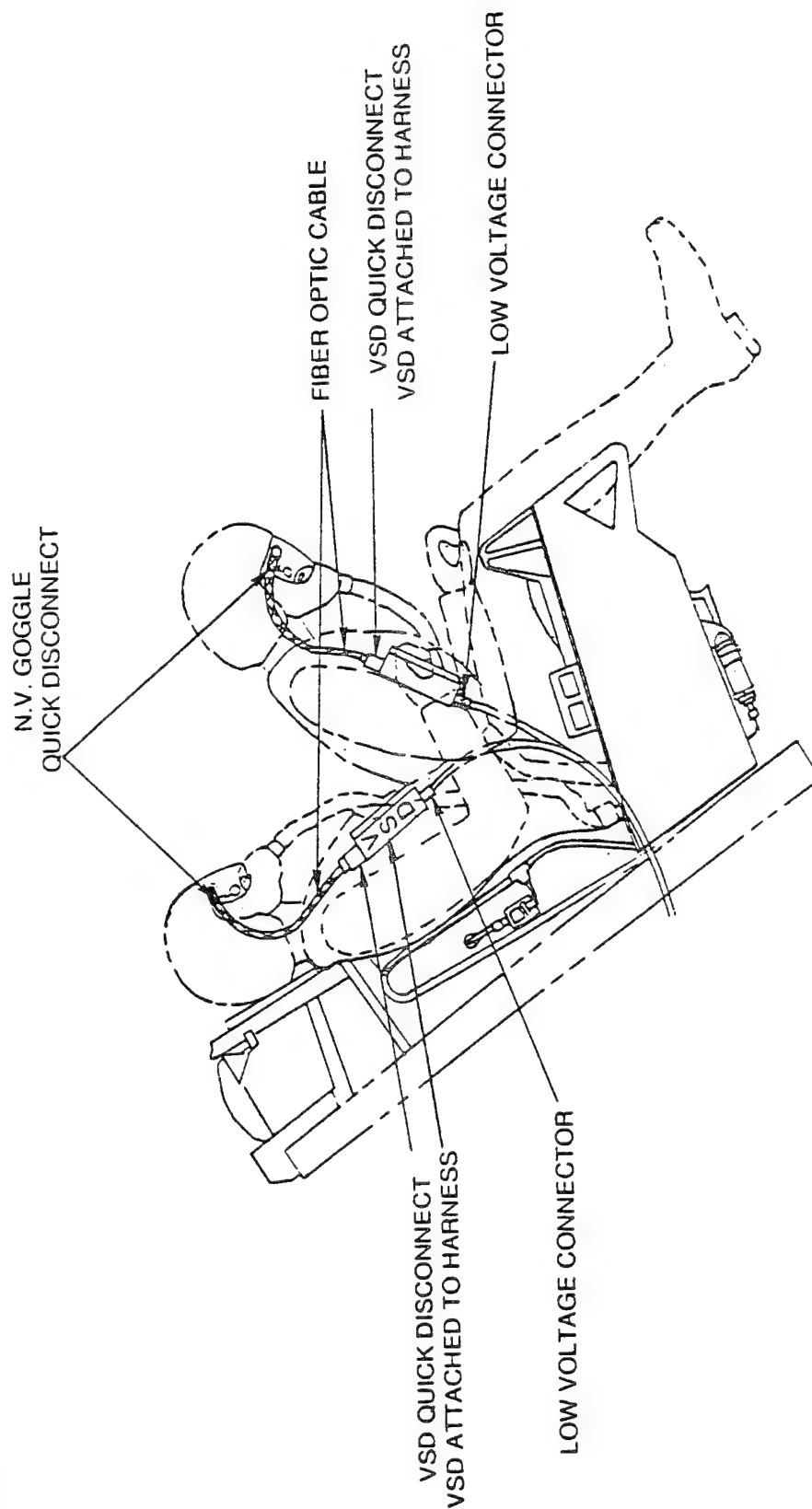


Figure 2-12
21

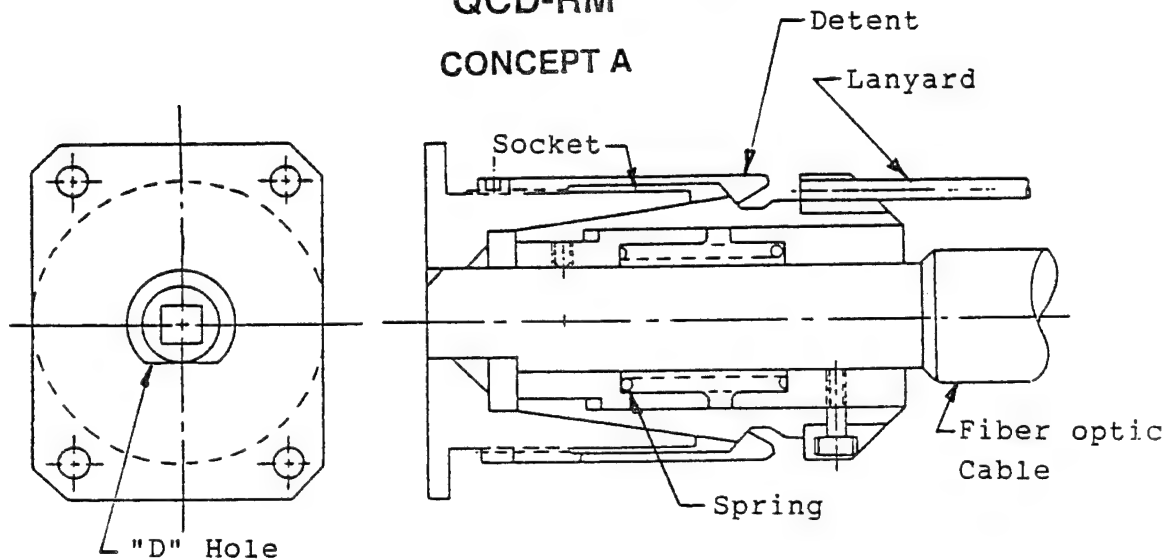
3.0 Quick Connect/Disconnects Concepts

The QCD-RM Concepts A thru E and I are designed to interface the VSD to the FOC. Concepts F, G and H are shown interfacing the other end of the FOC with the NVG HUD ports. Concept H shows an alternate approach of transmitting the fiber optic image to the HUD port of the Eagle Eye® NVGs. Concept H actually uses a concept E connector on the end of the cable.

Some of the concepts are described as FOC compliant. This means that these concepts permit the FOC end tip to float through the connector. A spring forces the end tip to remain in contact of the stop provided so the image plane does not shift due to temperature variations or interchangeability tolerances between different units. On each connector we have indicated the use of an antifriction coating on all mating surfaces. This material is both hard and impregnated with Teflon to achieve a self-curing, self-lubricating surface with low friction. This treatment will prevent crabbing or galling of a mating surface which impedes sliding between these surfaces. This is very critical when we wish to cause sliding with pulls that are at a large angle off axis, required for consistent release of the connectors.

TAPERED MECHANICAL DETENT F.O. CABLE COMPLIANT

QCD-RM CONCEPT A



3.1 QUICK CONNECT/DISCONNECT - CONCEPT A

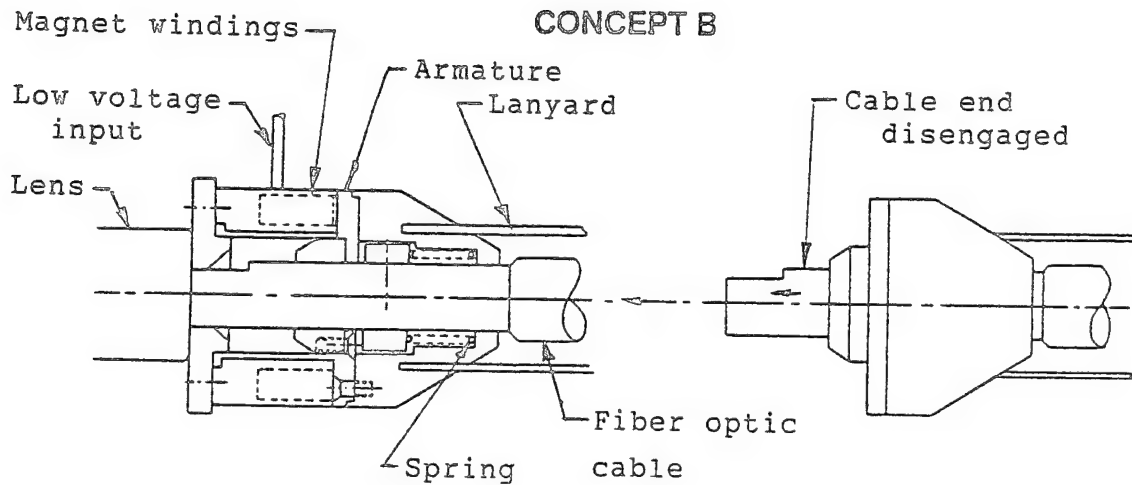
DESCRIPTION: Mechanical detents hold in a free releasing taper housing surrounding the FOC end. There is a three pound spring force on the cable end to insure compliance of the fiber cable end to an image plane over large temperature variation. The end of the fiber cable housing has a flat machined parallel to the square fiber optics aperture. This gives the end a "D" shape which keys the fiber optics image orientation to the night vision goggles. The removable cable end weighs 2 oz. and has a maximum diameter of 1.19 inches and is 2.85 inches long which is a standard length end.

This configuration allows at least $\pm 45^\circ$ or 90° cone angle of release pull with very small difference in the pullout force of 11.5 pounds. The tapered housing also protects the detent fingers from becoming over stressed during rapid egress or ejection.

The detents should retain the connector for greater than 15g forces in any direction. The mating surfaces and the detent surfaces are coated with NITUFF® a product to increase lubricity, reduce wear, and eliminate the possibility for crabbing in the connector.

To engage the connector simply insert the FOC end into the connector rotate to align with the "D" hole and continue to push in to a hard stop and detent finger engage cam surfaces. To release a pull on the lanyard or fiber cable will release the FOC from the connector. A lanyard is attached to the fiber cable connector and attached to the pilots harness. At rapid egress or ejection the lanyard will pull the cable free from the VSD.

ELECTRO-MAGNETIC QCD-RM



QUICK CONNECT/DISCONNECT - CONCEPT B

DESCRIPTION: An Electro-magnetic connector with a compliant FOC. This connector has a 3 pound spring force on the cable end to insure compliance of the fiber cable end to an image plane over large temperature variations. The end of the fiber cable has a "D" shape which keys the FOC and it's image to a correct orientation.

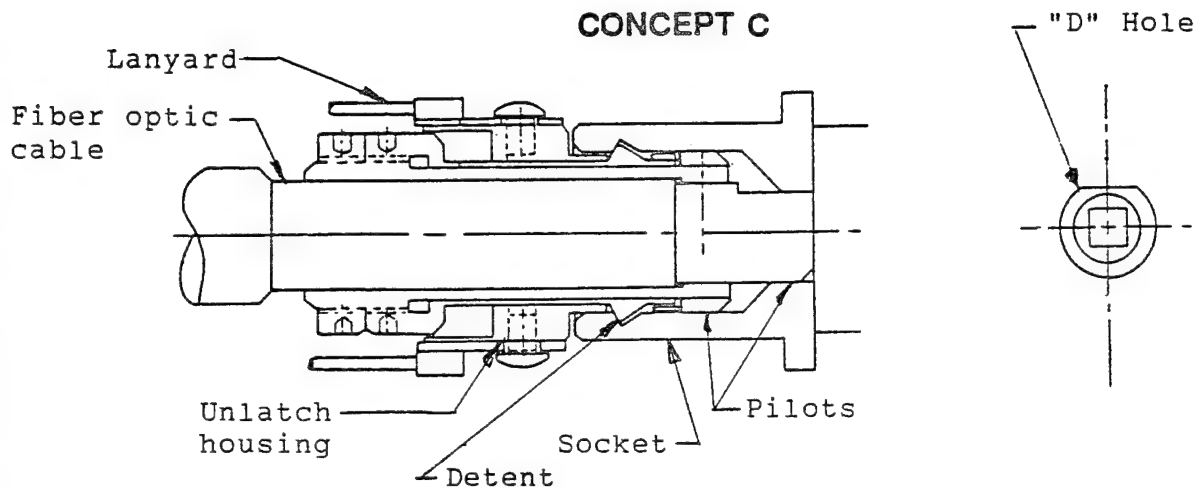
The removable portion of the quick disconnect weighs 4 oz and has a 1.62 inches diameter and a 2.85 inches length. This configuration allows at least $\pm 40^\circ$ or 80° cone of release pullout. The release force is 7 pounds. This should retain the connector for 15g force in any direction. The sliding surfaces are coated with NITUFF® a product to increase the lubricity, reduce wear, and eliminate the possibility of crabbing in the connector.

To engage of the FOC end turn on the electro-magnet and insert the cable end with it's taper guide into the magnet bore, rotating the cable to align the "D" shaped cable end with the "D" shaped seat. To release the cable end either turn off the magnet and freely remove the cable end, or in an emergency egress or ejection the lanyard attached to the pilots harness will release the FOC from the VSD unit.

The mating surfaces will be coated with an antifriction coating to prevent crabbing which could increase the release force. This will also allow a larger cone angle of pull for releasing the connector.

MECHANICAL DETENT PULL TO UNLATCH NONCOMPLIANT QCD-RM

CONCEPT C



MECHANICAL DETENT PULL TO UNLATCH - CONCEPT C

NONCOMPLIANT

DESCRIPTION: The FOC end is held in place with three mechanical detents which are internal to the connector socket. The cable end is piloted by the cable end tip and a ring which fit the pilot diameter of the socket. The detents are retracted inward with a pull on the lanyard. An eight pound pull is required to remove the cable end with the lanyard. A fail safe mode is a pull on the cable which would require a sixteen pound pull. The cable end weighs 3.4 oz and has a one inch diameter and 2.44 inches overall length. The cable has an adjustable depth setting, but is not self compliant to a stop or seat. It would be compliant within $\pm .008$ inches due to the detent design which would compensate for the temperature range, but would require a gauge setting to insure system interchangeability.

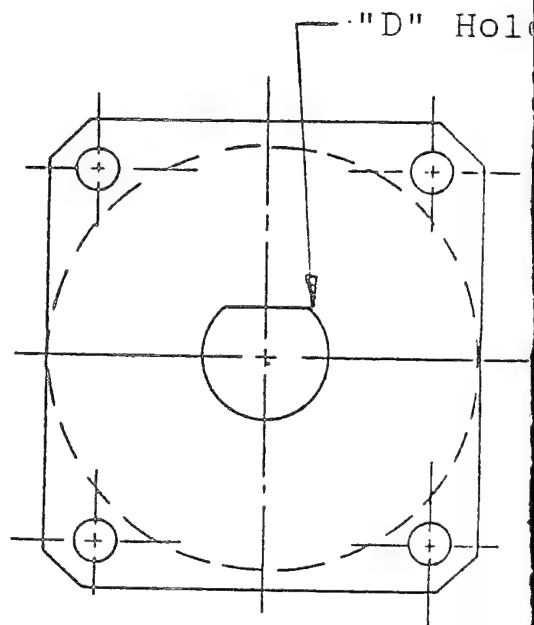
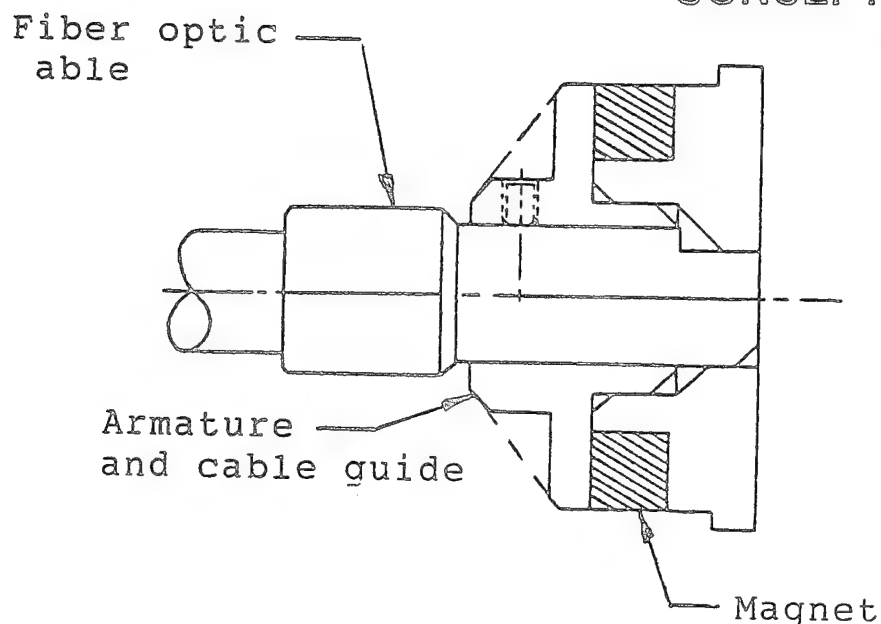
The insertion of the cable end is done by placing the end tip into the socket rotating to orient the tip with a "D" shaped hole and pushing forward to a hard stop. Releasing the cable is accomplished with a pull on the lanyard which is attached to the pilots harness, for both rapid egress and ejection.

The mating surfaces would be coated with an antifriction material to prevent crabbing causing an increase in the release force. This will also increase the pull angle for releasing the connector.

PERMANENT MAGNET CONFIGURATION

QCD-RM

CONCEPT D



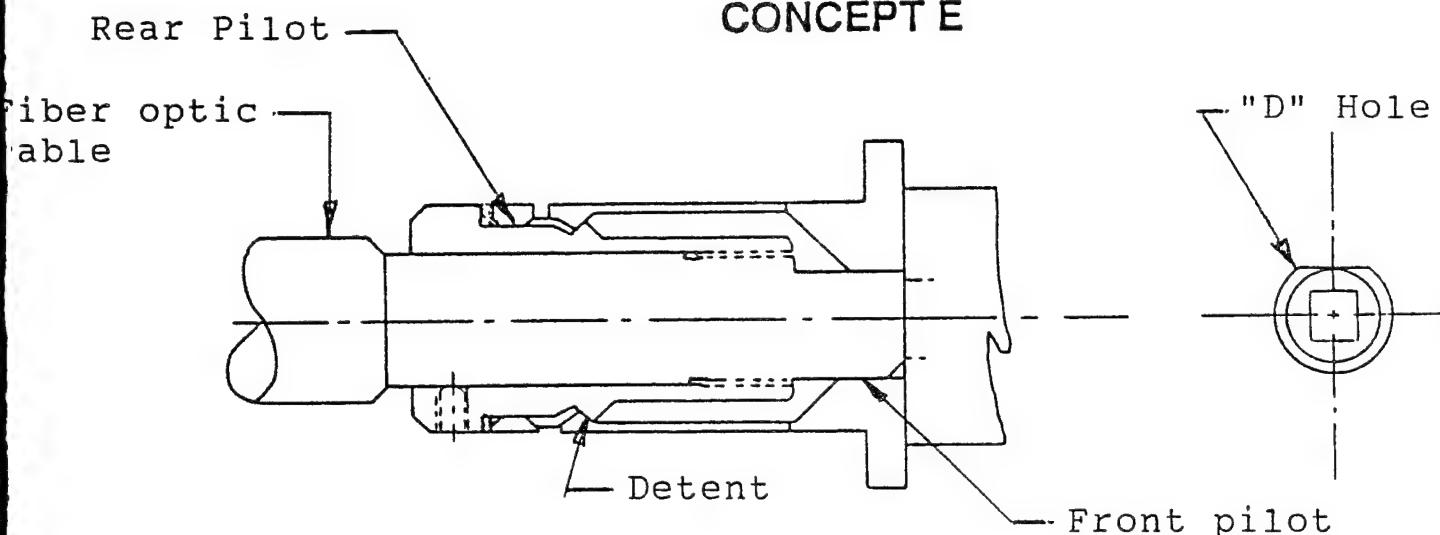
PERMANENT MAGNET TWO PILOT DIAMETER - CONCEPT D

NONCOMPLIANT QCD - RM

The permanent magnet ring would be made from neodymium-iron-boron which has the greatest energy density. This magnet needs a keeper placed over the magnet surface to protect it from picking up stray magnetic particles while not in use. This concept allows for the shortest cable end. The cable end is machined into a "D" configuration to key the fiber optics to a proper orientation. This connector is noncompliant and would require a gage to set the cable end location. The mating surfaces will be coated with an antifriction coating to prevent crabbing and increase the angle at which the connector can be released. The insertion and release of the cable end is done similarly to the concept "B".

MECHANICAL DETENT TWO PILOT DIAMETER NONCOMPLIANT QCD-RM

CONCEPT E



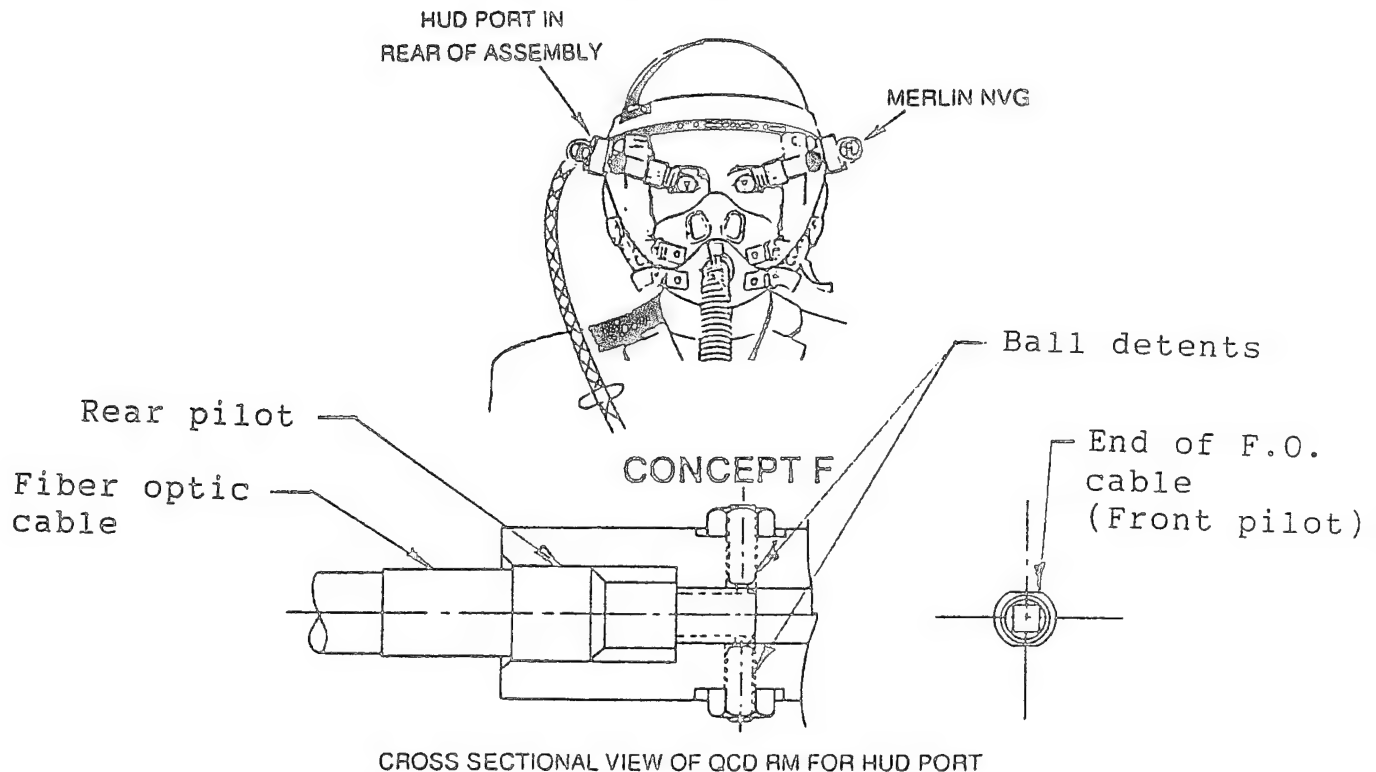
MECHANICAL DETENT TWO PILOT DIAMETERS - CONCEPT E

NONCOMPLIANT QCD - RM

DESCRIPTION: This connector has two pilot diameters one for the "D" section of the cable end and one at the receiving end of the socket. The detents are cut from the cylindrical socket with a special inside contour. The mating surfaces will be coated with an antifriction material to prevent crabbing thus permitting release by a pull anywhere within a 40° cone angle. This concept has the smallest outside diameter and lowest weight of the concepts presented. The connector can be made to have enough compliance to compensate for temperature variations but will need to set to a gage to insure interchangeability. The insertion of the cable end is done by placing the end tip into the socket and rotating to align the key and push forward to a hard stop. Releasing the cable is accomplished with a pull of 7 pounds on the cable.

ITT'S MERLIN N.V.G. WITH F.O. CABLE

CABLE QCD-RM

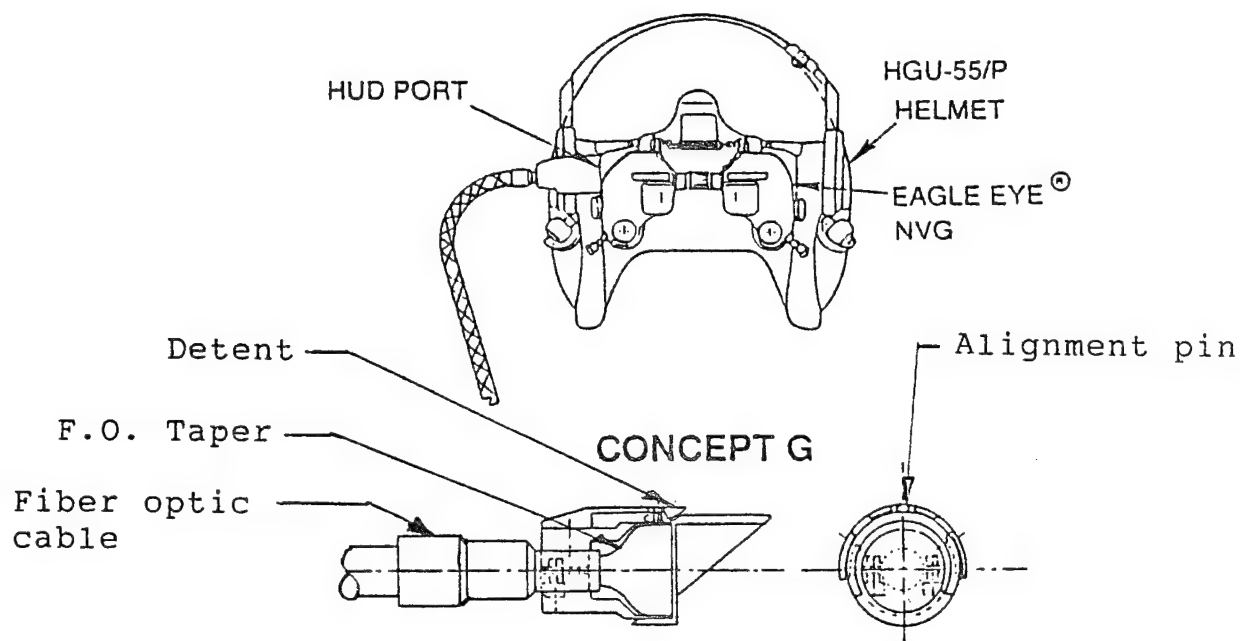


TWO DIAMETER PILOT WITH TWO BALL DETENT - CONCEPT F

This is a slight modification of the Merlin FOC by using two diameters to retain the cable. The purpose of the two diameters is to improve the releasing of the cable from it's socket. The mating surfaces will be coated with an antifriction material to prevent crabbing. The HUD port is inclined about 30° to the rear, and the maximum detent force would require a 9 pound release pull. The cable is finished with two flats 180° apart with two detent holes one in each flat. The flats are keyed to the image orientation, but since the two flats are identical the cable can have a 180° incorrect orientation. This can be resolved with a different configuration on the cable end.

The cable insertion is made similar to previous cables except a check needs to be made to insure a correct image orientation.

NVC/SRL'S EAGLE EYE[®] NVG WITH F.O. CABLE & TAPER & QCD-RM



CROSS SECTIONAL VIEW OF QCD-RM FOR HUD PORT

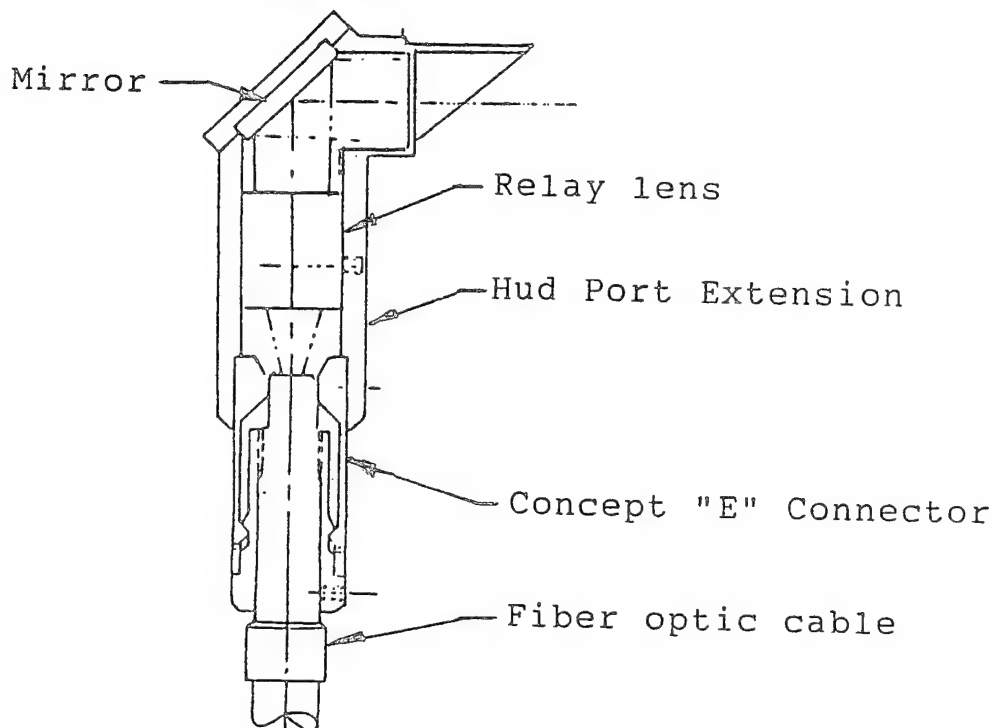
FIBER OPTICS CABLE AND TAPER - CONCEPT G

NONCOMPLIANT QCD - RM

This connector is designed for a quick disconnect for the Eagle Eye[®] NVGs. The HUD port is inclined 20° to the rear. The HUD port housing would require some modification to provide the detent capability required for a hands off disconnect. The housing has a pin to key the fiber optics orientation. The mating surfaces would be coated with an antifriction material to insure no crabbing and consistent release force. The release force would vary from 6 to 11 pounds depending on the angle of pull on the cable. The connector would probably disengage at a wind blast of 400 knots. Since the fiber optics taper needs to seat at the stop this makes the face of the taper vulnerable to being damaged. The insertion is accomplished with a push to the hard stop. Released can be accomplished with a pull through a greater than 90° cone angle.

ALTERNATIVE EAGLE EYE[®] QCD-RM RELAY LENS INSTEAD OF F.O. TAPER

CONCEPT H



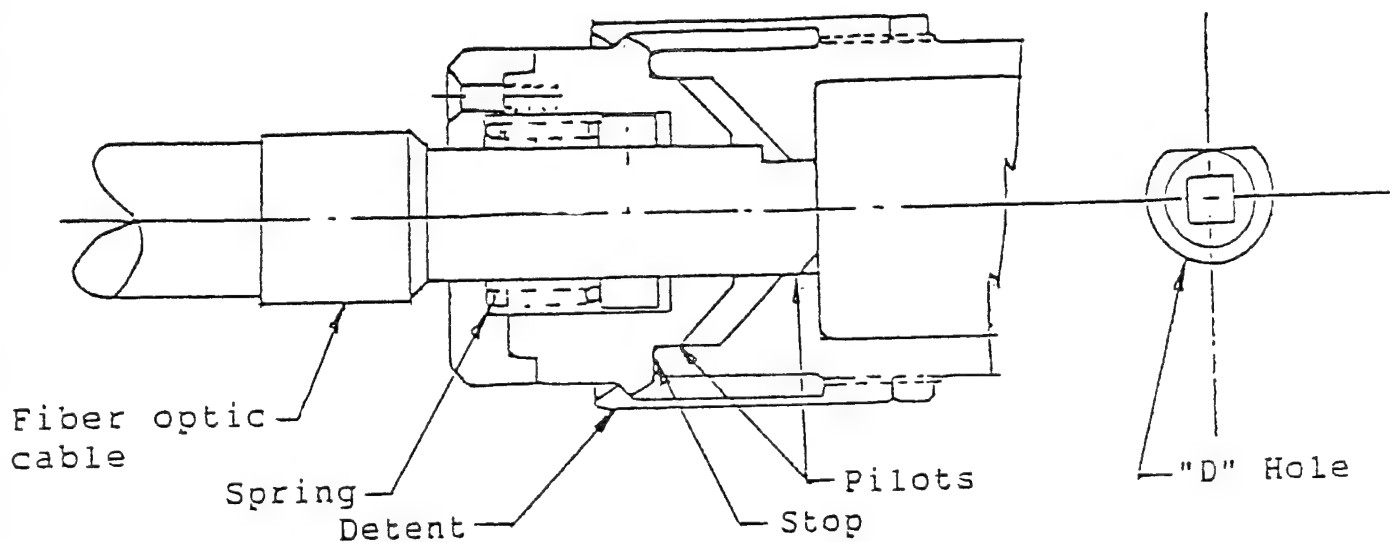
ALTERNATE EAGLE EYE WITH A RELAY LENS INSTEAD OF A FIBER OPTIC TAPER - CONCEPT H

This concept illustrates an alternative approach to present the fiber optic image to the HUD port. The advantage of this approach is to provide a fiber optic connector that will withstand the wind blast at ejection without disconnecting, but still allow a disconnect in the event of a loss of helmet. The connector is a Concept E QCD-RM, previously discussed. This concept replaces the fiber optics taper with a relay lens to present the FOC image to the HUD port. The only concern is that the relayed image may have an effect on the HUD port optical performance.

MECHANICAL DETENT LARGE RELEASE

ANGLE COMPLIANT F.O. CABLE

CONCEPT I



This concept is designed to interface at the top of the VSD rather than on the side. This location permits the use of a very short FOC to the NVG HUD port.

The connector permits the FOC to remain seated against its stop even through a large temperature variation. The mating surfaces are coated with a coating to harden and reduce the friction of these surfaces. The release angle should be greater than the 60° cone angle. This connector could be the disconnect point in the case of loss of helmet, which would eliminate any flailing of the cable in a strong wind blast.

FIBER OPTIC CABLE CONNECTOR CHARACTERISTICS

Q.O. TYPE		ON VSD ONLY										ON NVG'S ONLY		CABLE RESISTANCE AND ROUTING	
LOCATION OF Q.O.		Mech Detent Compliant A	Electro Magnet Compliant B	Mech Detent Pull to Initiate Non Compliant C	Permanent Magnet D	Mech Detent 2 Pilot Dia's Non Compliant E	Ball Detent Adjustable Force Non Compliant F	Mech Detent W/F O Taper Non Compliant G	Relay Lens Non Compliant For F.E. H						
Disconnect Wecking		3 OZ.	4 OZ.	3.4 OZ.	3 OZ.	1 OZ.	1 OZ.	2 OZ.	RELAY 3 OZ. 1 OZ. O.D.						
Disconnect Size	VSD ON HARNESS	1.25 ϕ x 2 1/2 LD. TOP: 9 3/4" SIDE: 2"	1.30 ϕ x 2 1/2 LD. NOT USED	1.0 ϕ x 2 3/4 LD. TOP: 9 3/4" SIDE: 2"	1.30 ϕ x 1 1/2 LD. TOP: 9 3/4" SIDE: 2"	.75 ϕ x 2 1/2 LD. 9 3/4"	.55 ϕ x 2 1/2 LD. 9 3/4"	1.0 ϕ x 2 25 LD 9 3/4"	.75 ϕ x 1 1/2 LD 9 3/4"						
	VSD ON SEAT	3"	3"	3"	3"	3"	3"	3"	3"						
	VSD ON PISTOL PANAL	4"	4"	4"	4"	4"	4"	4"	4"						
FORCE TO DISCONNECT		11.90	100		100										
VSD ON HARNESS	Q D TYP	LOW VOLTAGE ELECTRICAL AT VSD	NOT USED	LOW VOLTAGE ELECTRICAL AT VSD	LOW VOLTAGE ELECTRICAL AT VSD	LOW VOLTAGE ELECTRICAL AT VSD	LOW VOLTAGE ELECTRICAL AT VSD	AT NVG ON VSD IF HELMET IS BLOWN OFF	AT NVG ON VSD IF BLOWN OFF						
	VSD ON SEAT	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD						
	VSD ON PISTOL	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD	F.O. CABLE AT VSD						
COST EACH		\$500	\$525	\$650	\$350	\$400	\$200	\$200	\$400						
MAINTAINABILITY		EXCELLENT	GOOD MAY REQUIRE FIELD CLEANING	EXCELLENT	MAGNET NEEDS REOPEN	IF DETENT DAMAGED REPLACE	WEAR PROBLEM	JOINT AT F.O. CABLE TO F.O. TAPER							
MANUFACTURABILITY		GOOD	GOOD	GOOD	PROBABLY GOOD	REQUIRES MODACH SOME CLOSE TOL REQUIRES MAGNET	STD MFG PRACTICE SOME CLOSE TOL	THIN WALLS							
TECHNICAL INFO		LOW	LOW	LOW	LOW	LOW	VERY LOW	CABLE STICKS OUT MAY CAUSE PISTOL PANAL	OPTICAL DESIGN						
ADVANTAGES/ DISADVANTAGES		FIELD ANGLE SUPERIOR TO ALL OTHERS	MAGNET STRENGTH REQUIRES 20V	POTENTIAL FOCUS PROBLEMS	KEEP DIRT OFF MAGNET	VERY SMALL WALL ANGLE UNDER 10-45° CORSE			CLEARING MTOF SENSOR PATH						

This chart was developed to help evaluate the different concepts and their merit. Concepts A, B, C, D and E can be used on the VSD end of the FOC. Concepts F, G and H are specifically tailored to interface with one of the Night Vision Goggle HUD ports, or the opposite end of the FOC.

10 = MOST DESIRABLE

QUICK DISCONNECT CONFIGURATION

CONCEPTS

CHARACTERISTICS	VSD	VSD	VSD	VSD	*VSD OR	NVG	NVG	NVG
	A	B	C	D	E NVG	F MERLIN	G E.E.	H E.E.
DISCONNECT END WEIGHT	8	7	8	8	10	10	9	8
DISCONNECT SIZE	8	7	8	7	9	10	8	8
FORCE TO DISCONNECT	8	8	9	9	10	10	9	10
COST	8	8	7	8	9	10	10	9
DISCONNECT RELEASE CONE ANGLE (RISK)	10	5	4	5	4	4	7	4
MAINTAINABILITY	10	7	10	5	7	8	6	7
MANUFACTURABILITY	7	8	7	9	9	10	8	7
RELIABILITY	10	7	8	8	8	6	5	6
PERFORMANCE	10	9	6	7	6	6	6	6
PILOT INTERFERENCE	7	7	8	6	8	8	6	8
TECHNICAL RISK	9	9	9	9	8	10	8	7
TOTAL OUT OF 110	95	82	84	81	88	92	82	80

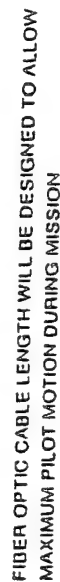
The chart ranks the different quick disconnect concepts in order to select one optimum configuration. The concepts A, B, C, D and E can be used on the VSD end of the FOC, while concepts F, G and H are tailored to interface with one of the NVG HUD ports at the opposite end of the FOC. Concept I was formulated later for use at the top side of VSD if a 9 $\frac{3}{4}$ inch cable was used and not included in this ranking chart.

Not all characteristics are of equal importance so it is easy to bias the ranking; however, the emphasis was applied as objectively as possible. For example, the force to disconnect is related to the weight and effects of pilot movement. On the HUD port end this force is also related to the wind blast effects which may not be attainable within the guide lines of 8-16 pounds of release force. Here the release force may be more related to how the cable is routed to minimize the exposed cable area.

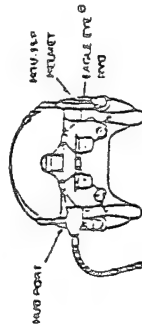
TAPERED MECHANICAL DETENT
F.O. CABLE COMPLIANT



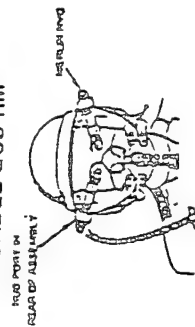
PILOT IN EXTREME FORWARD POSITION



NVC/5RL'S EAGLE EYE® NVG
WITH F.O. CABLE & TAPER & QCO-RM

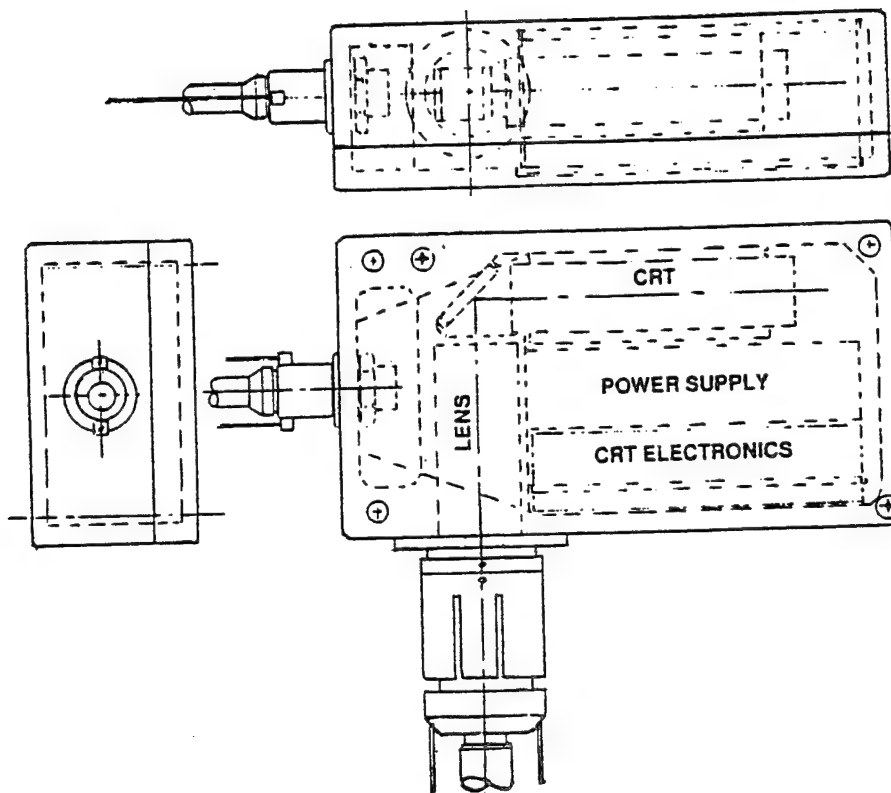


ITT'S MERLIN N.V.G. WITH F.O. CADLE
CABLE QCD-RM



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MINIATURIZED VIDEO SYMBOLOGY DISPLAY FOR FIGHTER AIRCRAFT



3.2 Proposed Minaturized VSD

The miniaturized VSD would be approximately 3 inches wide by 5.75 inches long and 1.62 inches thick. The weight including the connectors is about 1.4 pounds using plastic for the housing material. This is compared to 3x4x9 inches and 5.5 pounds for our current production VSD.

The input to the miniaturized VSD is low voltage power (28 volts at 3 watts max) and a video signal (± 1 volt). The CRT voltages are produced by a small internal power supply, and the video signal is processed by the internal electronic circuit. This eliminates the need for a high voltage disconnect without causing a hazardous electrical disconnect.

The three mounting configuration for the VSD mounting have been shown and in each configuration it is necessary to miniaturize the VSD package for high performance aircraft.

MINIATURIZED VIDEO SYMBOLOGY DISPLAY WITH
FIBER OPTIC AND ELECTRICAL CABLE QCD-RM'S

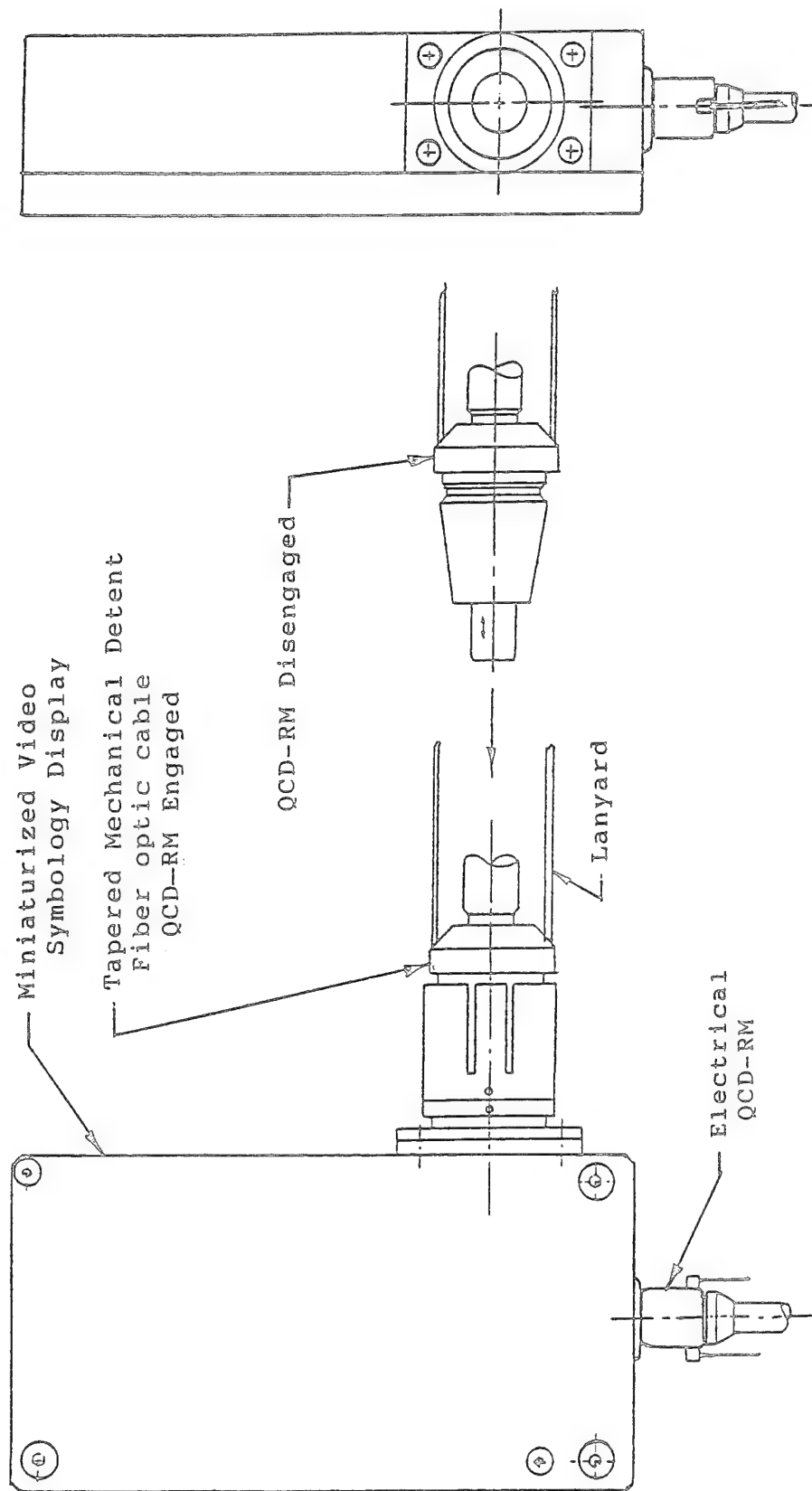


Figure 3-1
36

4.0 Phase II Statement of Work

The configuration selected for Phase II, based on a review of Phase I and guidance by the Biodynamics and Bioengineering Division of Wright Laboratory personnel involved, is as follows:

4.1 Video Signal Display Unit to be mounted on the cockpit seat.

A miniaturized VSD simulator will be produced for Phase II testing.

4.2 The Night Vision Goggle for fiber optic cable integration will be the Eagle Eye®.

4.3 Three quick connect/disconnect units will be required.

4.3.1 An electrical QCD for power and video signal to the VSD.

4.3.2 A VSD to FOC QCD for the video signal output.

4.3.3 A FOC to NVG HUD port to transfer the optical signal to the pilot's eye.

This configuration is illustrated in Figure 4-1.

4.4 Cable Routing

The Fiber Optic Cable should be routed in a manner as to not restrict the pilot's movement, either his body or head. The FOC should be made as flexible and light weight as possible while providing adequate protection for the integrity of the glass fibers. A trade-off matrix of FOC constructions should be made to facilitate the selection of an optimum cable design for this application.

PROPOSED QCD-RM AND SEAT MOUNTED VSD CONFIGURATION

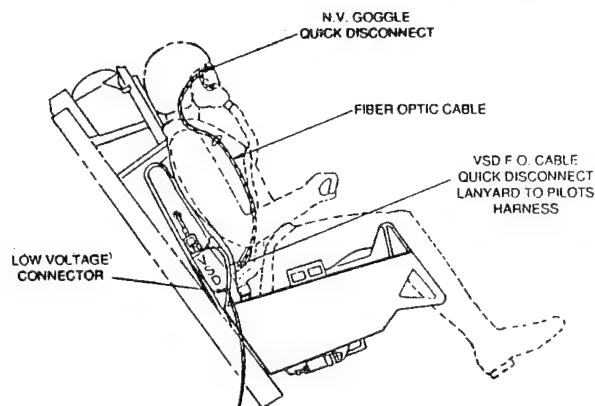


Figure 4-1

5.0 Task I, Fabricate and Test QCD-RM's..

At the kick-off meeting the Statement of Work parameters will be reviewed, the schedules confirmed and two FOC QCD's selected for development. The desired configuration and electrical QCD will also be confirmed if needed.

Design specifications and drawing will be generated for the second FOC QCD-RM, and the necessary interface alteration for the NVG HUD port. A first article of the two FOC QCD-RM will be fabricated. Test procedures will be written for the first article QCD-RM's and lab tested. A review of the results will be presented with design considerations if needed.

A quantity of ten (10) each of the two QCD-RM's will be fabricated and lab tested similar to the first article test. For schedule see Figure 9-3, 9-4 and 9-8 summary schedule and cost.

6.0 Task II, Fiber Optic Cable Design.

FOC requirements for a high performance airplane will differ considerably from the half inch diameter FOC presently in use with the SRL HUD. Light weight and high flexibility will be much more important in high performance aircraft than for helicopter use while less armor should be required in our case since the cable will not be routed throughout the cockpit. During the Phase I analysis of operational requirements, including review of the present FOC configuration, it was determined that a new cable design is mandatory. The proposed Task II encompasses both a review of the optical and mechanical requirements since they are closely inter-related.

A review of cable length and physical requirements will be accomplished to define mechanical properties including crush, shear and tensile specifications. Flexibility and minimum bend radius as a function of pilot motion, "g" forces and cable routing will be defined. Concurrently, an optical investigation will define the true pixel count required to produce the desired image format and image quality. The present 4mm x 4mm bundle format with individual 8 μ fibers on 10 μ centers will be the baseline; smaller formats and both smaller and larger individual fibers will be considered. Smaller formats with finer fibers may retain the same resolution but exhibit fiber breakage problems while the 4mm x 4mm format with larger fibers will have less resolution but greater resistance to breakage. The task II schedule is shown in Figure 9-5 and 9-8 shows the summary schedule and cost.

All major FOC manufacturers, including Galileo, Schott and Machida, will be contacted for their latest technology and ideas on fiber size, matrix layout, optical qualities, mechanical properties of the glass fibers and mechanical properties of various protective outer coverings. Nose piece design and the ability to

machine a suitable optically flat surface will also be addressed. Fiber breakage near the nose piece/cable armor interface is also an important issue. FOC fabricator data will be used to bound the physical and optical property investigations and continuous dialogue with the fabricators will ensure that the latest product alternatives are considered, including cost impact.

A trade-off matrix will be generated from manufacturer's and SRL analytical results, evaluating physical vs. optical properties of the FOC candidates. Cost, delivery risk, etc. will be factored into the final evaluation matrix. A summary of the matrix results will be prepared with a recommendation for the optimum cable/nose piece configuration to be purchased for the interface testing phase. A detailed procurement specification will be written subsequent to Government approval of all FOCs of choice when funding is made available by the Government.

7.0 Task III, Miniature VSD Paper Design.

A paper design will be generated for a miniaturized VSD. A brassboard circuit will be constructed to prove the design. A miniature VSD simulator will be designed and constructed to be used in the testing of the FOC QCD's. The simulator will have a fixed target of some typical HUD display and an adjustable light source to simulate the VSD brightness range. See Figure 9-6 for the Task III schedule and 9-8 for the summary schedule and cost.

8.0 Task IV, Interface Testing.

A bracket will be designed that can be clamped to a government selected and furnished seat structure. The seat structure will not be altered. The VSD simulator will be fastened to the bracket which will locate the VSD in the proper testing location. It is assumed that this can be done in a cockpit mock-up or even in an actual cockpit furnished by the government. It is also assumed that an Eagle Eye® NVG attached to a flight helmet will be GFE. A modification to the HUD port of the Eagle Eye® NVG will be required to accommodate the QCD-RM. This modification may be external to the existing HUD port, so as to be removed after testing. Then, with the help of a pilot with a standard flight suit and helmet with an attached Eagle Eye® NVG, a normal pre/post flight operation of connecting and disconnecting of the FOC QCD's can be evaluated. The performance of the QCD's on rapid egress will also be evaluated. Helmet loss due to wind blast will have to be simulated in a lab experiment. See Figure 9-7 for the schedule and 9-8 for the summary schedule and cost. The cost estimates are figured fully loaded for the ROM.

9.0 Phase II Program Recommendations.

Investigation of the QCD-RM design in Phase I clarified the issues which should be addressed in Phase II, particularly the need to miniaturize the FOC and electronic components within the HUD VGG and VSD units. An overall Phase II roadmap was presented to the Air Force to illustrate all of the design issues identified and suggest a time phased plan for their accomplishment. Figure 9-1 is the Phase II QCD-RM development, integration and test roadmap including the required design option inputs from AL/CFA. Conceptually, the roadmap breaks down four specific tasks:

1. QCD-RM development
2. Electronic design of miniaturized electronics and FOC
3. Test aircraft system layout and integration
4. Flight test investigation of mechanical and optical properties of the QCD-RM and it's related system components.

Tasks 1, 2 and 3 can be pursued independently to a certain point, either simultaneously or sequentially.

AL/CFA down selected a subset of the tasks from the roadmap and expanded the detail in their recommended effort. Figure 9-2 is the Air Force's selection of roadmap tasks which have been further detailed, estimated for labor hours and schedule and ROM costed (fully loaded) by SRL. FOC design, Task II in Figure 9-2, was recognized as a critical path item for successful system accomplishment, additionally impacting HUD functionality, man-machine interface and QCD-RM integration. The proposed Phase II program detailed in the following sections has been derived from the development, integration and test program outlined in Figure 9-2. SRL is confident that all of the technical challenges can be met in the time and ROM cost estimated.

AL/CFEA (HMST) INPUTS

- VSD CONFIGURATION
- IN COCKPIT
- ON SEAT
- ON PILOT

- CHOOSE GOGGLE TYPE

- EAGLE EYE
- MERLIN

- CHOOSE CONNECTOR TYPES TO PRODUCE

- VSD ELECTRICAL
- VSD FOC
- GOGGLE FOC

- CABLE REDESIGN

- B-52 STANDARD
- VS. NEW MINI-CABLE

- VSD LEVEL OF SIMULATION

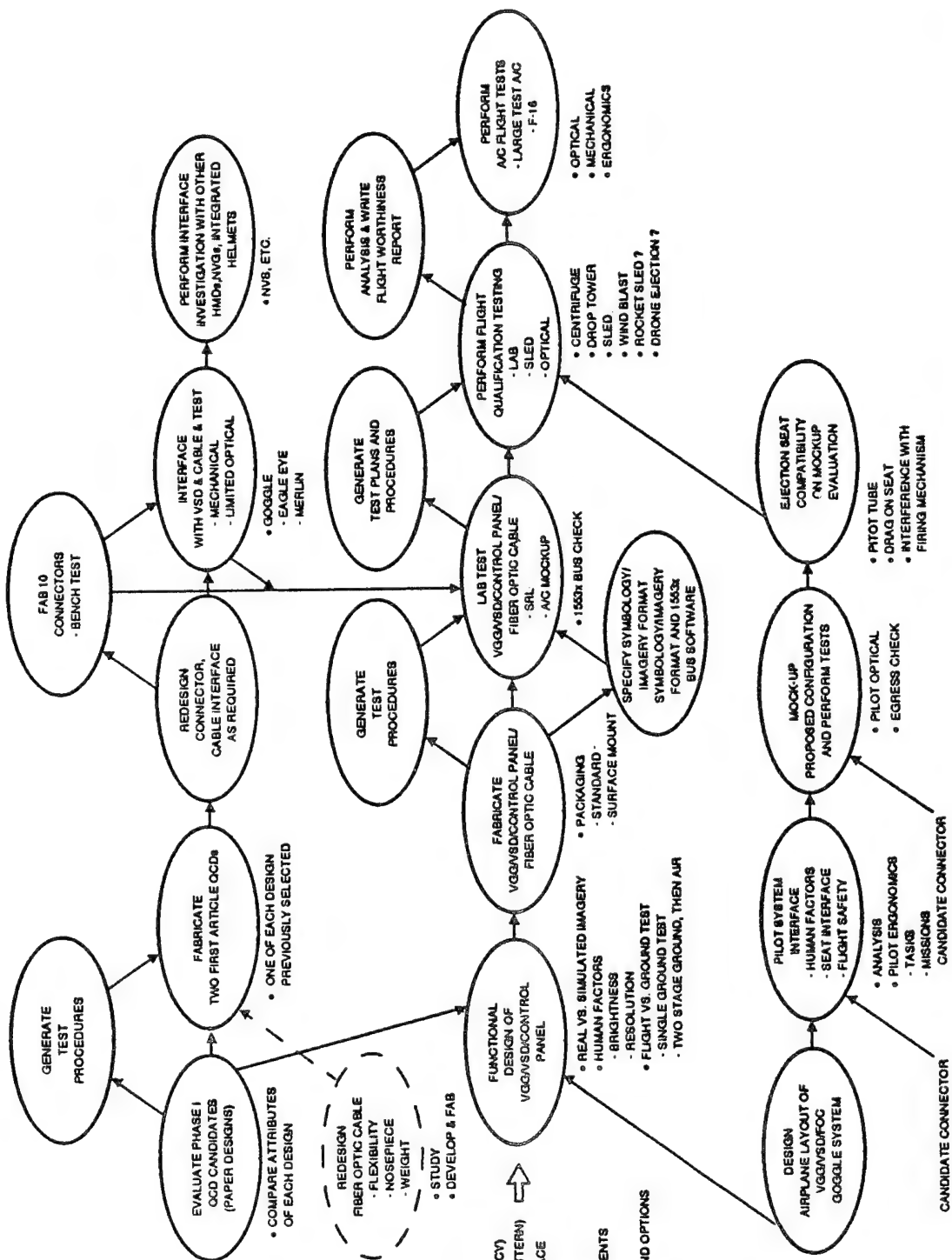
- FIXED PICTURE (TRANSPARENCY)
- ELECTRONIC IMAGE (TEST PATTERN)
- FULL AC & 1553x BUS INTERFACE AND ASSOCIATED IMAGERY

- IMAGERY/SYMBOLOLOGY REQUIREMENTS

- AF SOCIETY
- SRL INVESTIGATE, RECOMMEND OPTIONS

- CHOOSE AC TEST PLATFORM

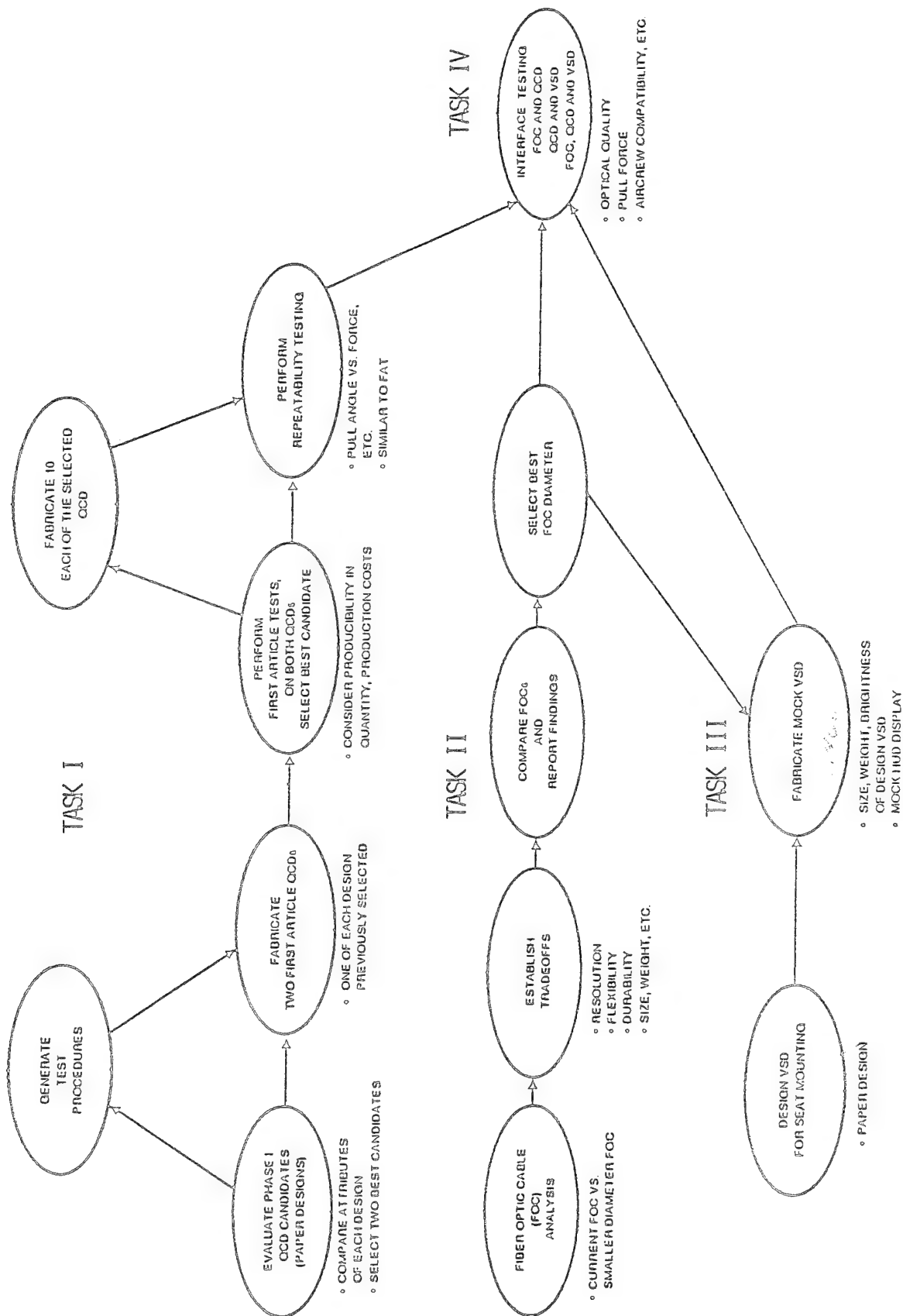
- B-52
- F-16
- AF CHOICE



PHASE II QCD/RM DEVELOPMENT, INTEGRATION AND TEST ROAD MAP

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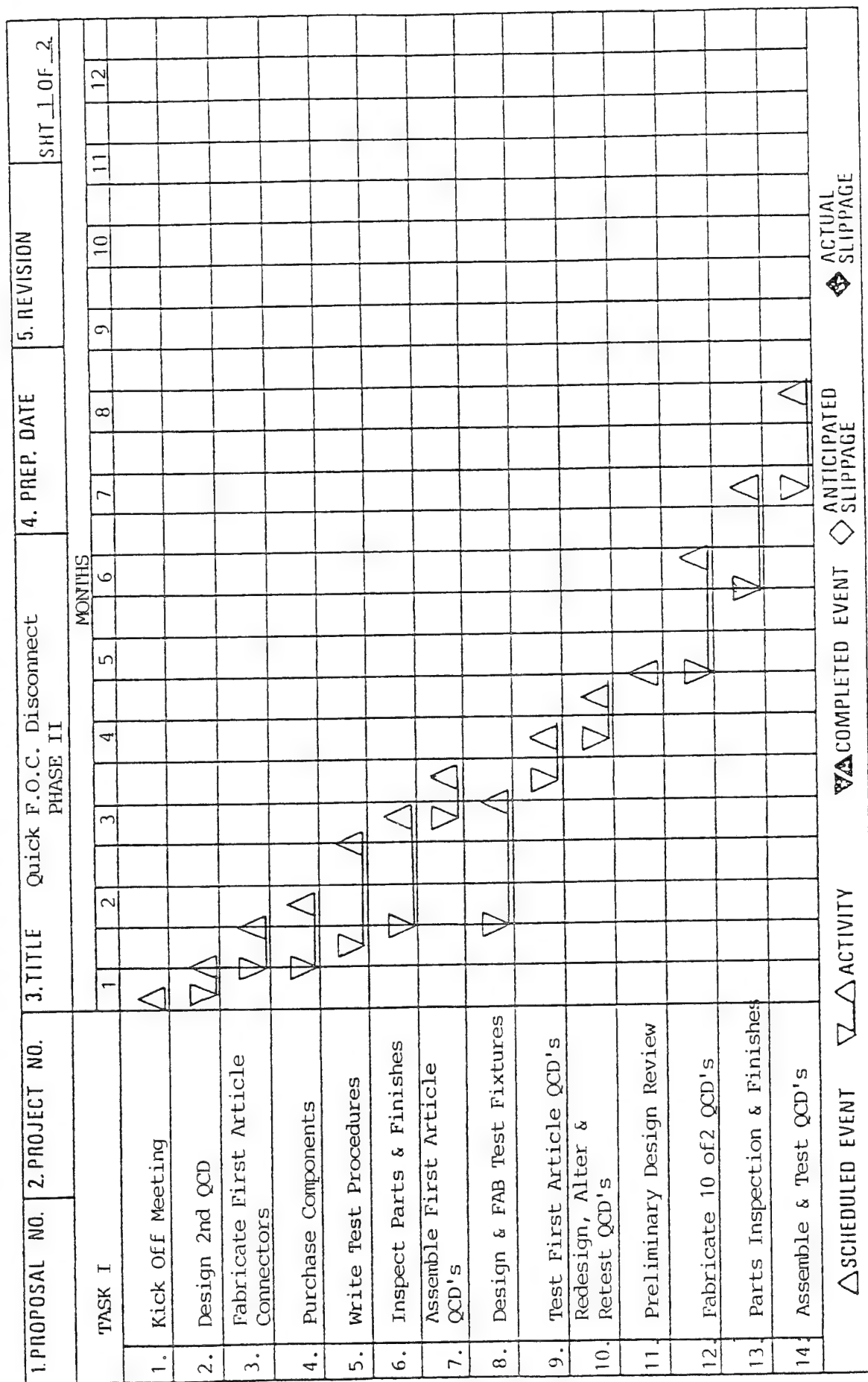
Figure 9-1
41



PHASE II QCD/RM DEVELOPMENT, INTEGRATION AND TEST PROGRAM

570200069

Figure 9-2
42



PROGRAM DETAIL SCHEDULE

1. PROPOSAL NO.		2. PROJECT NO.		3. TITLE Quick F.O.C. Disconnect PHASE II		4. PREP. DATE		5. REVISION		SHT 1 OF 1						
SUMMARY SCHEDULE				MONTHS												
				1	2	3	4	5	6	7	8	9	10	11	12	
TASK I				▽									△			
TASK II				▽				△								
TASK III				▽				△								
TASK IV										▽		△				
TASK I 90,690																
TASK II 31,640																
TASK III 50,760																
TASK IV 12,170																
TOTAL 185,260																

PROGRAM DETAIL SCHEDULE

Figure 9-8

APPENDIX A

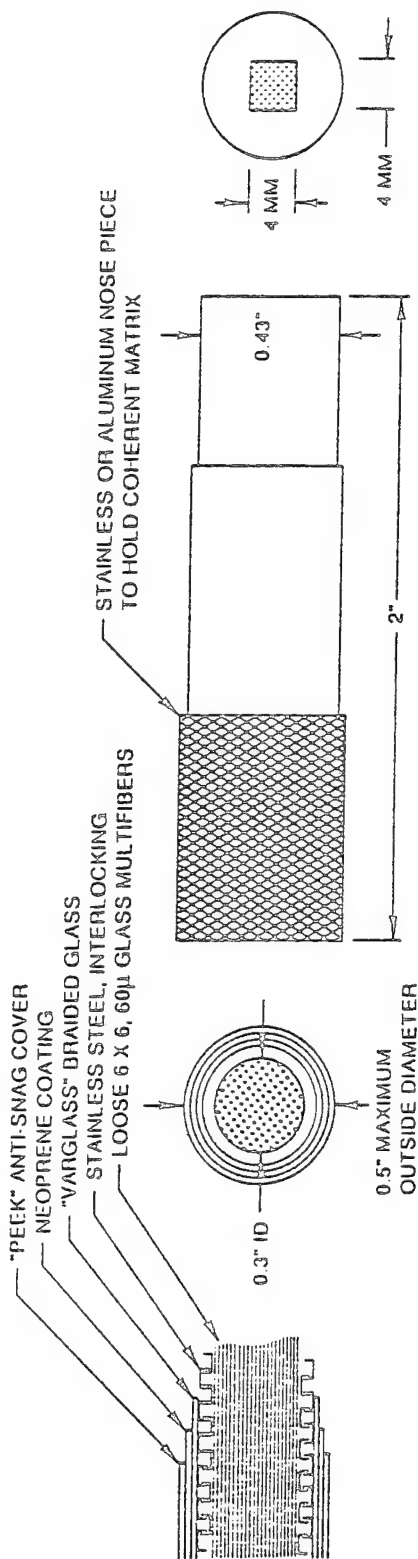
FIBER OPTIC CABLE CONSTRUCTION AND OPTICAL RESOLUTION

The FOC construction of the presently used FOC is larger and not as flexible as desired for this application. Figure A1 shows the construction of the present FOC and a proposed lighter weight and more flexible FOC.

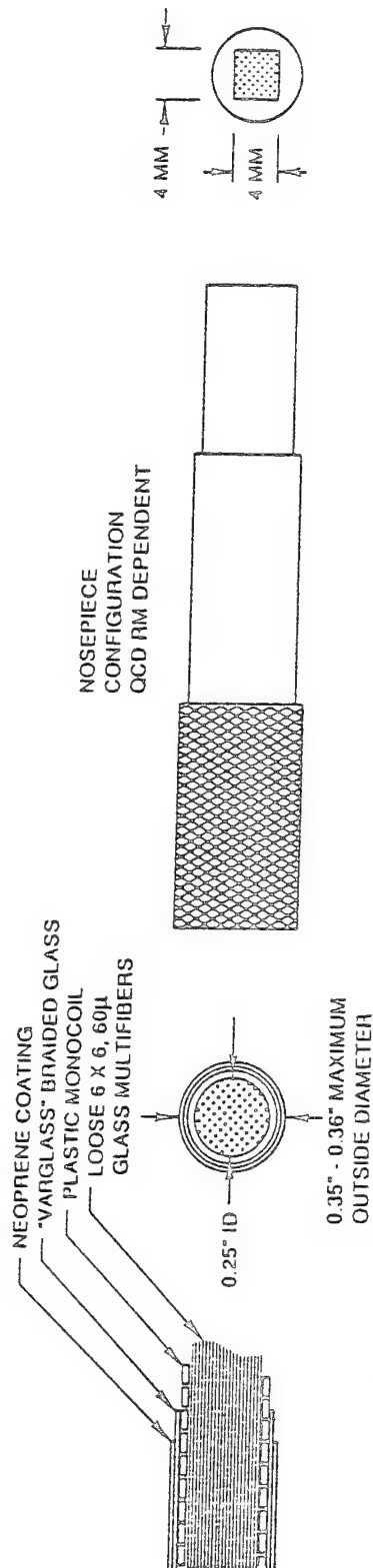
A study was made of the coupling effects for FOC's. Photographs of the resolution through various combinations illustrate some of the coupling problems. Figure A2 is a photograph of the exit end of a FOC where an image of the standard Air Force resolution chart at unity magnification was placed on the input end of the FOC. The 5-4 elements are clearly visible which represents a resolution 45 line pairs per mm. The theoretical resolution of this cable is 50 lp/mm based on the fiber size and spacing, which would be 5-5. Figure A3 is set up with the FOC used in Figure A2 plus another cable butted to the output end of the first cable. Then a photograph was taken of the exit end of the second cable. The limiting resolution in this photo is 5-1 or 32 lp/mm or a loss of approximately 13 lp/mm because of the coupling of the two FOC's. Figure A4 is a photograph of the output of a second FOC butted to the first with mineral oil at the interface between the two FOC's. The limiting resolution is 5-1 the same as in Figure A3. There may be some intensity difference but not a noticeable difference in resolution.

It appears that coupling two FOC's in a mechanical manner causes a considerable loss in resolution. With a fiber taper and relay lens a smaller loss in resolution was measured. A coupling fluid did not appear to improve the resolution although the index of refraction between the fiber and the fluid was not a good match. A better match would theoretically help. Figure A5 is a photograph of the output of a fiber optic taper assembled to the end of a FOC. The limiting resolution is 5-3 or 40 lp/mm. This is only 5 lp/mm less than was observed on the straight FOC. The taper gives a 3:1 magnification of the end of the FOC. The exit end of the taper has approximately 8μ diameter fibers so the end butted to the fiber cable output would have approximately 2.67μ diameter fibers. Statistically there should be three taper fibers for each FOC fiber, however they never align themselves that well. This combination shows much less loss than the two cables butted together. Figure A6 has one FOC set up as in Figure A2 plus a lens to give 3:1 magnification in place of the fiber taper. This also had a limiting resolution of 5-3 or 40 lp/mm. Figure A6 shows the image at the exit end of the FOC. The input is an image of a resolution chart relayed by a 16mm focal length lens on the entrance end of the FOC.

FIBER OPTIC CABLE CONSTRUCTION

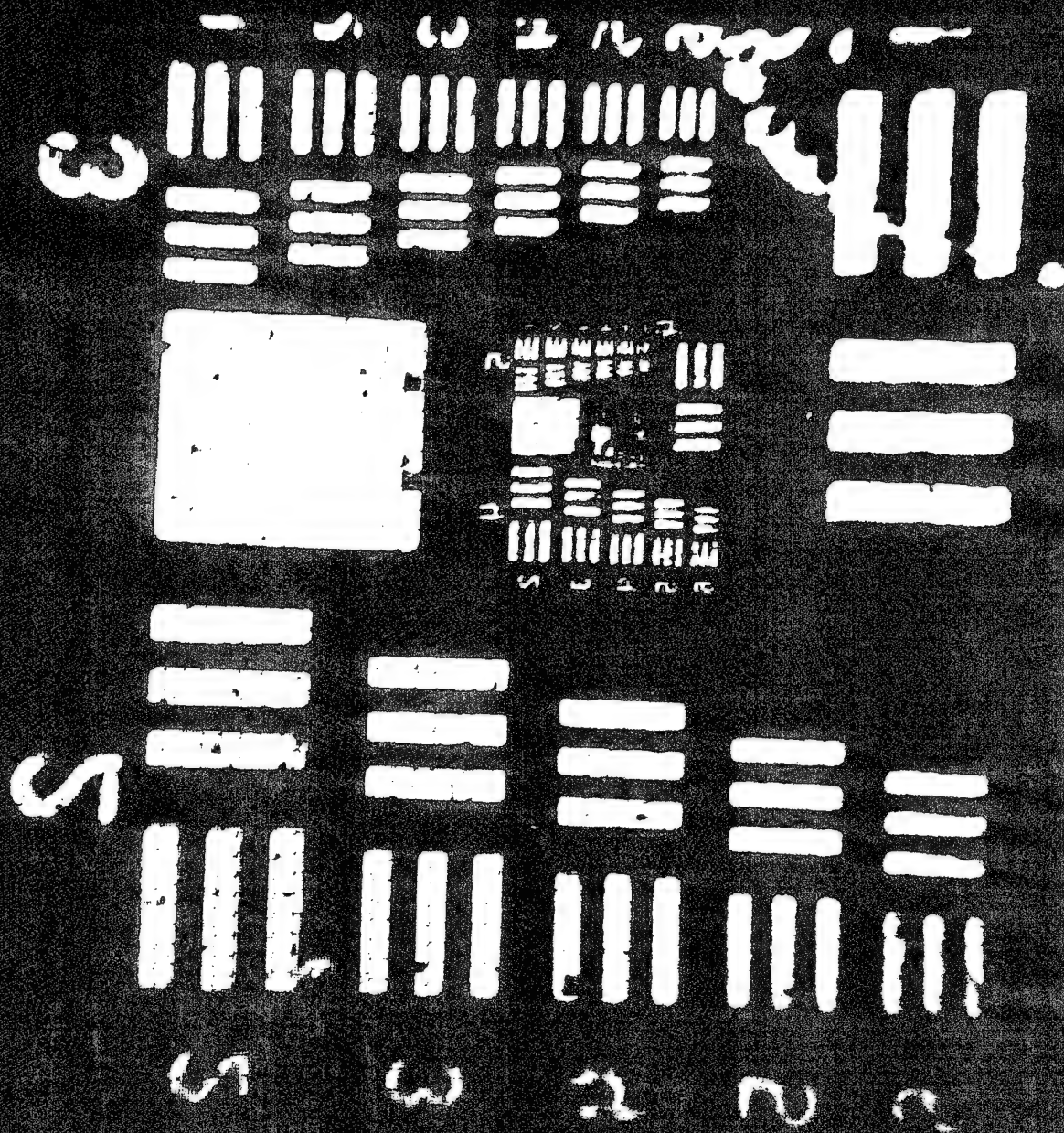


PRESENT ANVIS / HUD FOC

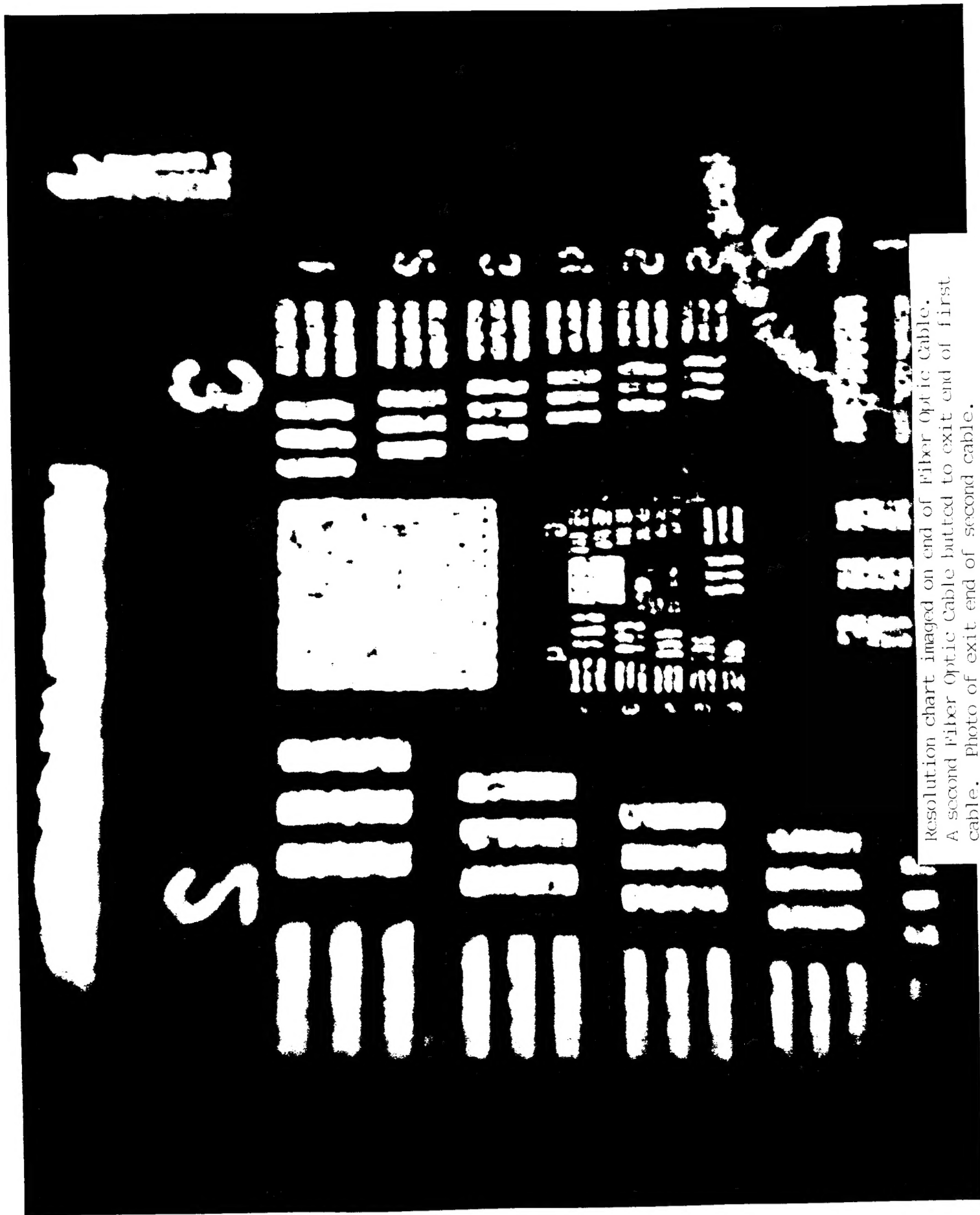


PROPOSED FOC FOR QCD RM CONFIGURATION

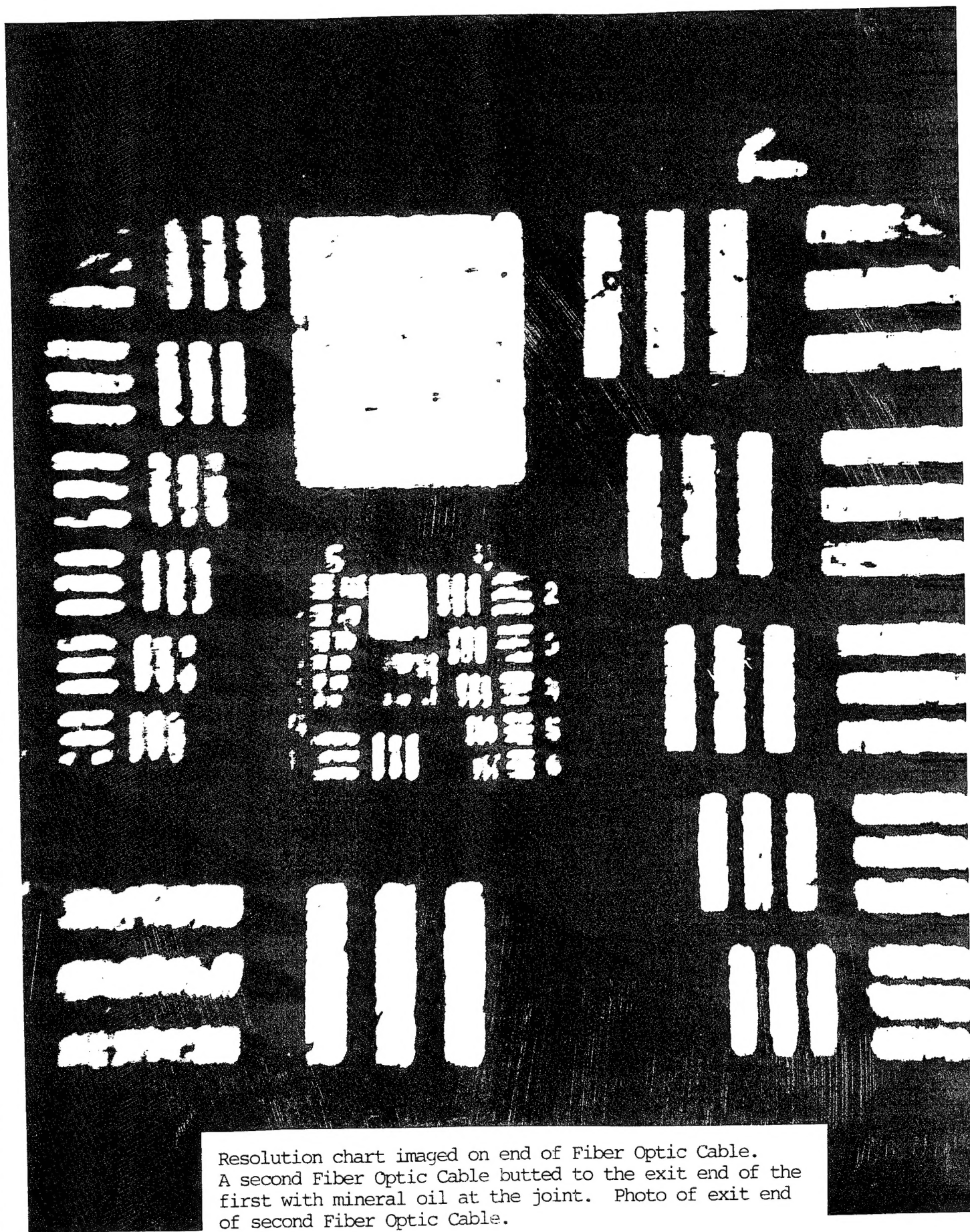
Figure A1
50



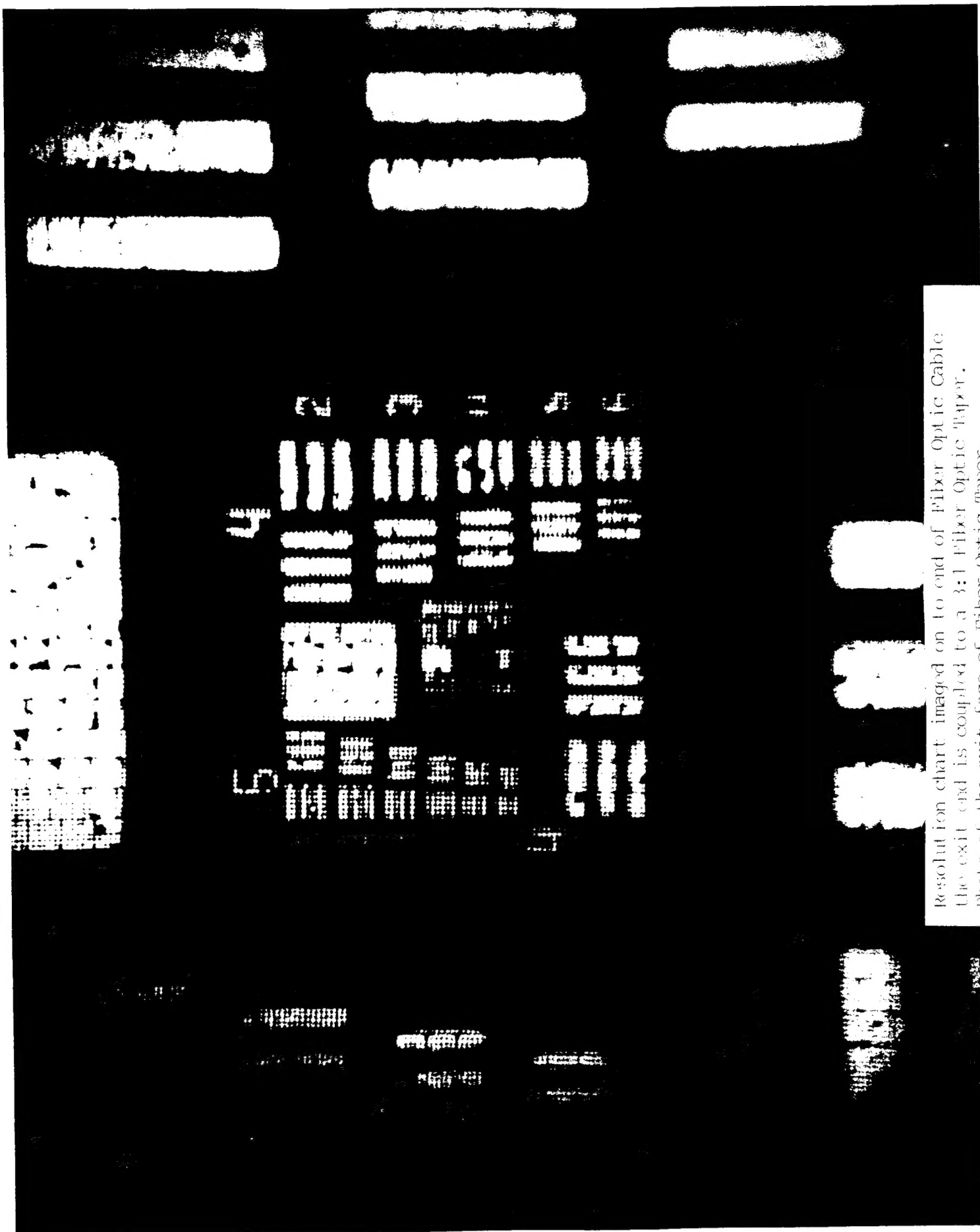
Resolution chart imaged on end of Fiber Optic Cable.
Photo of exit end of Fiber Optic Cable.



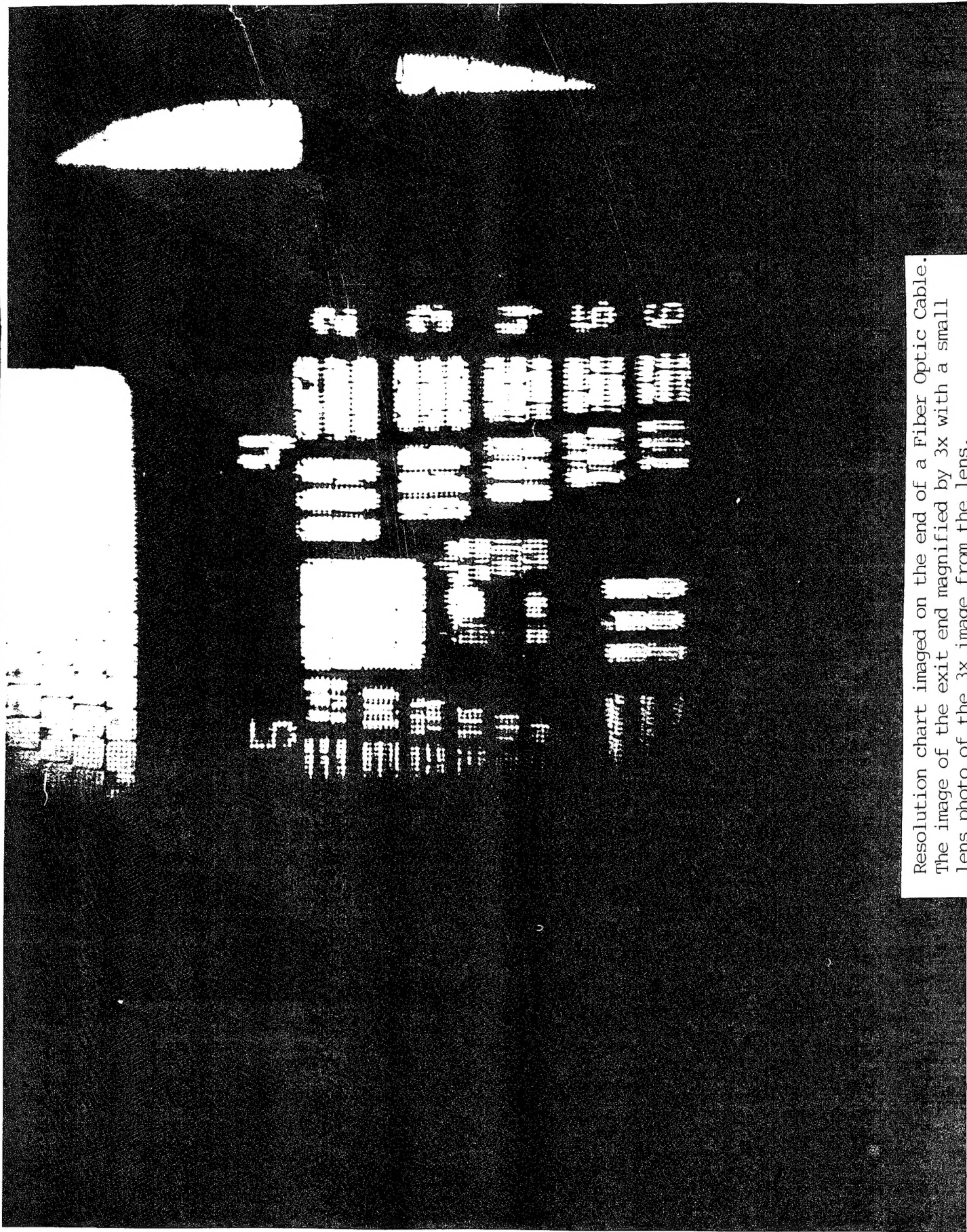
Resolution chart imaged on end of Fiber Optic Cable.
A second Fiber Optic Cable butted to exit end of first
cable. Photo of exit end of second cable.



Resolution chart imaged on end of Fiber Optic Cable.
A second Fiber Optic Cable butted to the exit end of the
first with mineral oil at the joint. Photo of exit end
of second Fiber Optic Cable.



Resolution chart imaged on to end of Fiber Optic Cable
the exit end is coupled to a 3:1 Fiber Optic Taper,
photo of the exit face of Fiber Optic Taper.



Resolution chart imaged on the end of a Fiber Optic Cable.
The image of the exit end magnified by 3x with a small
lens photo of the 3x image from the lens.